European Commission

JRC SCIENTIFIC AND POLICY REPORTS

PV STATUS REPORT 2012

Arnulf Jäger-Waldau

EUR 25749 - 2012

Joint Research Centre

Europe Direct is a service to help you find answers to your questions about the European Union

Freephone number (*): 00 800 6 7 8 9 10 11

(*) Certain mobile telephone operators do not allow access to 00 800 numbers or these calls may be billed.

More information on the European Union is available on the Internet (http://europa.eu).

Cataloguing data can be found at the end of this publication.

ISBN 978-92-79-26072-8 (online)

doi: 10.2788/44375 (online)

Luxembourg: Publications Office of the European Union, 2012

Printed in Belgium

Printed on elemental chlorine-free bleached paper (ECF)

This publication is a Scientific and Policy Report by the Joint Research Centre of the European Commission.

This study has been undertaken by the Joint Research Centre, the European Commission's in-house science service, to provide evidence-based scientific support to the European policy-making process.

The scientific output expressed does not imply a policy position of the European Commission.

European Commission
Joint Research Centre
Institute for Energy and Transport

Contact information
Dr. Arnulf Jäger-Waldau
Address: Joint Research Centre, Via Enrico Fermi 2749, TP 450, 21027 Ispra (VA), Italy
E-mail: arnulf.jaeger-waldau@ec.europa.eu@ec.europa.eu
Tel.: +39 0332 789119
Fax: +39 0332 789268

http://iet.jrc.ec.europa.eu/renewable-energies
http://www.jrc.ec.europa.eu/

Legal Notice

JRC74171
EUR 25749 EN

ISBN 978-92-79-26072-8 (online)
ISSN 1977-7086/1831-9424 (online)
doi: 10.2788/44375 (online)

Report EUR 25749 EN

Design: sailer design communication, Meersburg, Germany

PV Status Report 2012

Research, Solar Cell Production and Market Implementation of Photovoltaics

October 2012

Arnulf Jäger-Waldau
European Commission, DG Joint Research Centre,
Institute for Energy and Transport, Renewable Energy Unit
Via Enrico Fermi 2749; TP 450 I – 21027 Ispra (VA), Italia

EUR 25749 EN

Preface

In June 2009, the European Directive on the “Promotion of the Use of Energy from Renewable Sources“ went into force and does not only set mandatory targets for the Member States in 2020, but also gives a trajectory how to reach them. The aim of the Directive is to provide the necessary measures for Europe to reduce its greenhouse gas emissions by 20% in 2020, in order to support the world-wide stabilisation of the atmospheric greenhouse gases in the 450 to 550 ppm range.

In 2010, the IEA estimated in its Energy Technology Perspectives 2010, that the additional investment requirements in the power sector between 2010 and 2050, compared to the *“Baseline Scenario“* of $23.5 trillion (€18 trillion), would be $9.3 trillion (€7.15 trillion) for the *“Blue Map Scenario“* (450 ppm). At first sight, this looks like a lot of additional investment, but it is much less than the continuation of the fossil fuel subsidies. In 2010, the direct consumption subsidies in developing countries were $409 billion (€315 billion) and the support to fossil fuel in OECD countries added another $45 and 75 billion (€34.6 – 57.7 billion). Over 40 years this would sum up to almost $19 trillion (€14.6 trillion). Compared to these figures, subsidies to renewable energy are small, quoted with $66 billion (€50.8 billion), out of which $44 billion (€33.8 billion) went to renewable electricity in 2010.

At the end of 2011, the European Commission presented its Energy Roadmap 2050, and in its *Communication on Renewable Energy*, in June 2012, highlighted the need to decide on new post-2020 targets before the originally set timeframe in 2018. The discussion about renewable energy targets for 2030 is heating up, and the European Renewable Energy Council (EREC) already presented its request to set a 45% renewable energy target for the European Union for 2030.

Photovoltaics is a key technology option to realise the shift to a decarbonised energy supply. The solar resources in Europe and world-wide are abundant and cannot be monopolised by one country. Regardless for what reasons, and how fast the oil price and energy prices increase in the future, photovoltaics and other renewable energies are the only ones to offer a reduction of prices, rather than an increase in the future.

From 2008 to second quarter of 2012, residential PV electricity system prices have decreased by almost 60% in the most competitive markets, and in some markets, the cost of PV-generated electricity is already cheaper than residential electricity retail prices. Due to falling PV system prices and increasing electricity prices, the number of such markets is steadily increasing. The consequences of the nuclear accident which took place in Fukujima in March 2011, was a shift in energy investments toward more renewables and photovoltaic systems. In 2011, solar energy attracted 48.5% of all new renewable energy investments or $128 billion (€98.5 billion). Investments in distributed photovoltaic energy systems increased to over $71 billion (€54.6 billion).

In 2011, the photovoltaic industry production increased by almost 40% and reached a world-wide production volume of about 35 GWp of photovoltaic modules. Yearly growth rates over the last decade were on average between 40% and 90%, which makes photovoltaics one of the fastest growing industries at present.

The Eleventh Edition of the “PV Status Report” tries to give an overview about the current activities regarding Research, Manufacturing and Market Implementation. Over the last fifteen years, the photovoltaic industry has grown from a small group of companies and key players, into a global business where information gathering is getting more and more complex. Not every country and development is treated with the same attention, but this would go beyond the scope of this report. Any additional information would be highly welcome and will be used for the update of the report.

Ispra, October 2012

Arnulf Jäger-Waldau

European Commission
Joint Research Centre, Renewable Energy Unit

0. Table of Content

1. Introduction

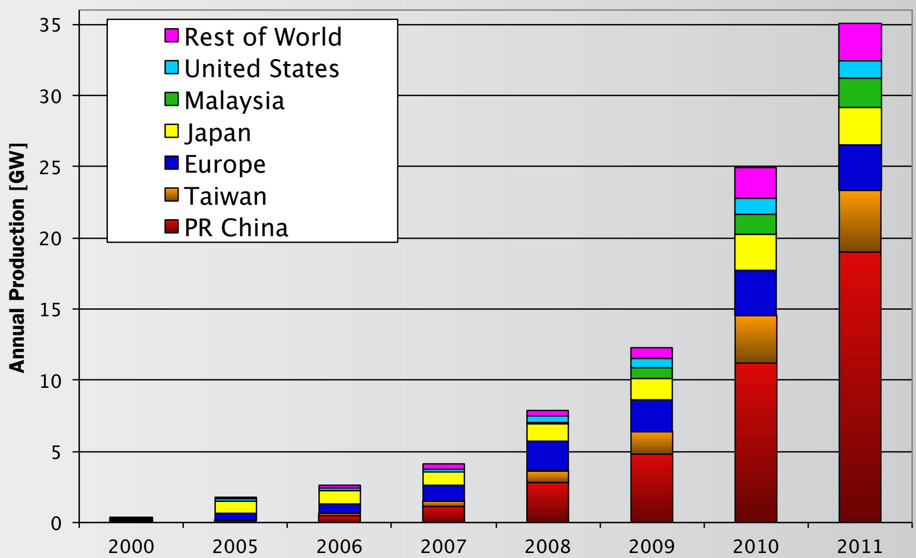
Production data for the global cell production[1] in 2011 vary between 30 GW and 37 GW. The significant uncertainty in this data is due to the highly competitive market environment, as well as the fact that some companies report shipment figures, while others report sales and again others report production figures. Another uncertainty is the fact that some companies sometimes produce less solar cells than solar modules, but the reporting does not always differentiate between the two. Therefore, some of the solar cell production can be counted double if they are attributed to the original cell manufacturer and then again to the company producing both cells and modules. In addition, the difficult economic conditions and increased competition led to a decreased willingness to report confidential company data. The year was characterised by a sluggish first half year and a boom in the fourth quarter of 2011.

The data presented, collected from stock market reports of listed companies, market reports and colleagues, were compared to various data sources and thus led to an estimate of 35 GW (Fig. 1), representing an increase of 37 % compared to 2010.

Since 2000, total PV production increased almost by two orders of magnitude, with annual growth rates between 40 % and 90 %. The most rapid growth in annual production over the last five years could be observed in Asia, where China and Taiwan together now account for more than 65 % of world-wide production.

[1] **Solar cell production capacities mean:**
- In the case of wafer silicon based solar cells only the cells
- In the case of thin-films, the complete integrated module
- Only those companies which actually produce the active circuit (solar cell) are counted
- Companies which purchase these circuits and make cells are not counted

Fig. 1: World PV Cell/Module Production from 2000 to 2011 (data source: Photon International [Pho 2012], PV News [Pvn 2012] and own analysis)



Public-traded companies manufacturing solar products, or offering related services, have attracted a growing number of private and institutional investors. In 2011, world-wide new investments into the renewable energy and energy efficiency sectors increased to a new record of $263 billion (€202 billion[2]), including $25.8 billion (€19.8 billion) research and development spending [Pew 2012]. More than 85% or $225 billion (€173 billion) of these investments are non-governmental, non-research clean energy investments. These investments resulted in a record of 83.5 GW of new clean energy generation capacity, bringing the total to more than 565 GW or 50% more than the installed nuclear generating capacity world-wide.

For the second year in a row, solar power attracted the largest amount of new investments into renewable energies [Pew 2012]. The 44% increase in solar energy investments to $128 billion (€98.5 billion) offset a 15% decline in both wind and energy efficiency investments. Asset finance grew by 12% to $141 billion (€108 billion), investments in distributed photovoltaic projects grew 25% to $71.5 billion (€55 billion) and venture capital and private equity investments grew by 8.6% to reach 8.6 billion (€6.6 billion), whereas public and private research and development investments fell 18% to $26 billion (€20 billion) [Pew 2012].

Europe was still the leading region in terms of renewable energy investments (without research and development spending), totalling $87.7 billion (€67.5 billion), followed by Asia/Oceania with $75 billion (€57.7 billion) and the Americas with $63.1 billion (€48.5 billion) [Pew 2011]. However, renewable energy investments in the Asia/Oceania region again grew faster than in Europe, mainly through major investment increases in India, Japan and Indonesia.

At the end of 2011 about 73% or $141.6 billion (€108.9 billion) of the $194.3 billion (€149.5 billion) global “green stimulus” money from governments, aimed to help relieve the effect of the recession, had reached the markets [Pew 2012]. For 2012 another $35 billion (€26.9 billion) are expected.

The existing over-capacity in the solar industry has led to a continuous price pressure along the value chain and resulted in a reduction of spot market prices for polysilicon material, solar wafers and cells, as well as solar modules of 50% over the last two years [Blo 2012]. These rapid price reductions are putting all solar companies under enormous pressure and the access to fresh capital is key to survival. It is believed that this situation will continue for at least the next few years and put further pressure on the reduction of the average selling prices (ASP), even if the overall reductions will not be as large as in the last years. The continuation of the financial crisis added pressure as it resulted in higher government bond yields, and ASPs have to match to allow for higher project internal rate of returns (IRRs). On the other hand, the declining module and system prices already opened new markets, which offer perspectives for further growth of the industry – at least for those companies with the capability to expand and reduce their costs at the same pace.

Despite the problems of individual companies, business analysts are confident that the industry fundamentals, as a whole, remain strong and that the overall photovoltaics sector will continue to experience significant long-term growth. In July 2012, the IEA published, for the first time, a *Medium-Term Renewable Energy Market Report,* which forecasts a more than threefold increase of cumulative PV installations in 2017, compared with 2011 [IEA 2012].

Market predictions for the 2012 PV market vary between 28.4 GW in the Bloomberg conservative scenario [Blo 2012], 30 to 31 GW by Solarbuzz and IMS research [Sol 2012, Ims 2012], and 35.4 GW in the Bloomberg optimistic scenario [Blo 2012]. In the first half of 2012, global installations of PV electricity systems have exceeded 13 GW, with Germany (4.37 GW), Italy (1.8 GW) and USA (1.7 GW) as the leading markets.

Despite a number of bankruptcies and companies idling production lines, or even closing down their production permanently, the number of new entrants into the market is still high and massive capacity increases are underway, or announced, and if all of them are realised, the world-wide production capacity for solar cells would exceed 80 GW at the end of 2012. This indicates that even with the optimistic market growth expectations, the planned capacity increases are way above the market growth. The consequence is the continuation of the overall low utilisation rate and therefore, a continued price pressure in an over-supplied market. Such a development will accelerate the consolidation of the photovoltaics industry and spur even more mergers and acquisitions.

The current solar cell technologies are well established and provide a reliable product, with sufficient efficiency and energy output for at least 25 years of lifetime. This reliability, the increasing potential of electricity interruption from grid overloads, as well as the rise of electricity prices from conventional energy sources, add to the attractiveness of photovoltaic systems.

[2] Exchange rate: 1 € = 1.30 US$

About 85 % of the current production uses wafer-based crystalline silicon technology. A major advantage of this technology is that complete production lines can be bought, installed and be up and producing within a relatively short time-frame. This predictable production start-up scenario constitutes a low-risk placement with calculable return on investments. However, the temporary shortage in silicon feedstock and the market entry of companies offering turn-key production lines for thin-film solar cells, led to a massive expansion of investments into thin-film capacities between 2005 and 2009. More than 200 companies are involved in the thin-film solar cell production process, ranging from R&D activities to major manufacturing plants.

Projected silicon production capacities available for solar in 2012 vary between 328,000 metric tons [Ihs 2012] and 410,330 metric tons [Ikk 2012]. The possible solar cell production will, in addition, depend on the material used per Wp. The current world-wide average is about 6 g/Wp.

Similar to other technology areas, new products will enter the market, enabling further cost reduction. Concentrating Photovoltaics (CPV) is an emerging market. There are two main tracks – either high concentration > 300 suns (HCPV), or low to medium concentration with a concentration factor of 2 to approx. 300. In order to maximise the benefits of CPV, the technology requires high Direct Normal Irradiation (DNI) and these areas have a limited geographical range – the "Sun Belt" of the Earth. The market share of CPV is still small, but an increasing number of companies are focusing on CPV. In 2011, about 60 MW of CPV were installed and market estimates for 2012 are varying in between the 10 to 70 MW range [Min 2012]. In addition, dye-cells are getting ready to enter the market as well. The development of these technologies is accelerated by the positive development of the PV market as a whole, but the competition for the right business case it becoming more fierce.

It can be concluded that in order to maintain the extremely high growth rate of the photovoltaic industry, different pathways have to be pursued at the same time:

- Further reduction of material consumption per silicon solar cell and Wp, e.g. higher efficiencies, thinner wafers, less wafering losses, etc.;

- Accelerated ramp-up and cost reduction of thin-film solar cell manufacturing;

- Accelerated CPV introduction into the market, as well as capacity growth rates above the normal trend;

- Development of new business models for the collection, sale and distribution of photovoltaic electricity, e.g. development of bidding pools at electricity exchanges, virtual power plants with other renewable power producers and storage capacities;

- Adaptation of the regulatory and legal procedures to ensure a fair and guaranteed access to the electricity grid and market.

Further photovoltaic system cost reductions will depend not only on the technology improvements and scale-up benefits in solar cell and module production, but also on the ability to decrease the system component costs, as well as the whole installation, projecting, operation, permitting and financing costs.

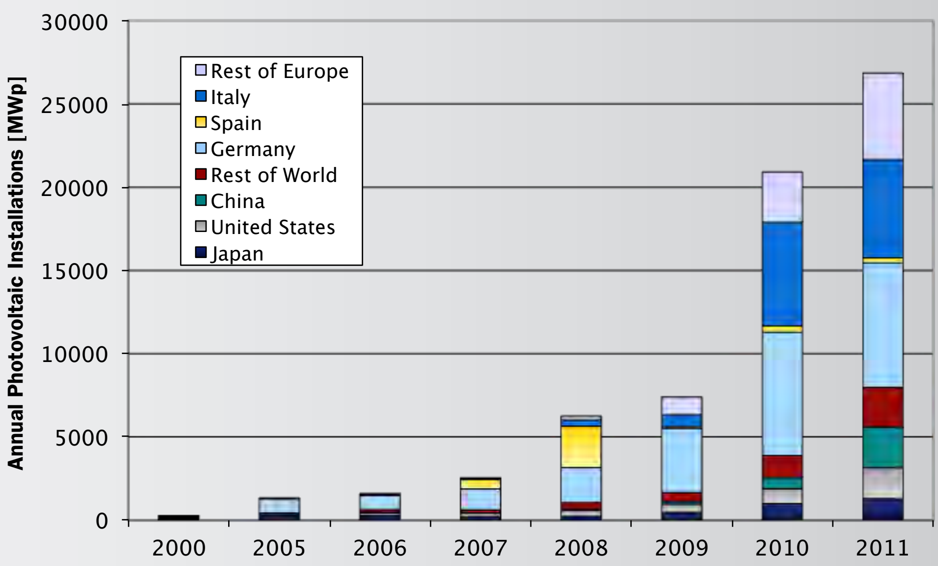
2. The Photovoltaic Market

After the world-wide photovoltaic market more than doubled in 2010, the market grew again by almost 30% in 2011, despite difficult economic conditions. The 2010 market volume of 20.9 GW includes those systems in Italy, which were reported under the second *"conto energia"* and probably already installed, but not yet connected. The continuation of the strong market in Italy and a year-end rush in Germany, where in the 4th quarter about 4 GW (3 GW in December alone) in conjunction with rapidly growing markets outside Europe in China and the USA resulted in a new installed capacity of almost 27 GW (Fig. 2). This represents mostly the grid-connected photovoltaic market. To what extent the off-grid and consumer product markets are included is not clear, but it is believed that a substantial part of these markets are not accounted for, as it is very difficult to track them. A conservative estimate is that they account for approx. 400 to 800 MW (approx. 1-200 MW off-grid rural, approx. 1-200 MW communication/signals, approx. 100 MW off-grid commercial and approx. 1-200 MW consumer products). With a cumulative installed capacity of over 51 GW, the European Union is leading in PV installations with more than 70% of the total world-wide 70 GW of solar photovoltaic electricity generation capacity at the end of 2011.

2.1 Asia & Pacific Region

The Asia & Pacific Region continued its upward trend in photovoltaic electricity system installations. There are a number of reasons for this development, ranging from declining system prices, heightened awareness, favour-

Fig. 2: Annual Photovoltaic Installations from 2000 to 2011 (data source: EPIA [Epi 2012], Eurobserver [Sys 2012] and own analysis)



able policies and the sustained use of solar power for rural electrification projects. Countries such as Australia, China, India, Indonesia, Japan, Malaysia, South Korea, Taiwan, Thailand, the Philippines and Vietnam show a very positive upward trend, thanks to increasing governmental commitment towards the promotion of solar energy and the creation of sustainable cities.

The introduction or expansion of feed-in tariffs is expected to be an additional big stimulant for on-grid solar PV system installations for both distributed and centralised solar power plants in countries such as Australia, China, Japan, Malaysia, Thailand, Taiwan and South Korea.

The Asian Development Bank (ADB) launched an Asian Solar Energy Initiative (ASEI) in 2010, which should lead to the installation of 3 GW of solar power by 2012 [ADB 2011]. In their report, ADB states: *Overall, ASEI aims to create a virtuous cycle of solar energy investments in the region, toward achieving grid parity, so that ADB developing member countries optimally benefit from this clean, inexhaustible energy resource.*

Three interlinked components will be used to realise the ASEI target:

Knowledge management: Development of a regional knowledge platform dedicated to solar energy in Asia and the Pacific.

Project development: ADB will provide $ 2.25 billion[3] (€1.73 billion) to finance the project development, which is expected to leverage an additional $ 6.75 billion (€5.19 billion) in solar power investments over the period.

Innovative finance instruments: A separate and targeted Asia Accelerated Solar Energy Development Fund has been set up to mitigate risks associated with solar energy. The fund will be used for a buy down programme to reduce the up-front costs of solar energy for final customers. ADB aims to raise $500 million (€ 385 million) and design innovative financing mechanisms in order to encourage commercial banks and the private sector to invest in solar energy technologies and projects.

Innovative finance instruments: Setting up of a separate and targeted Asia Accelerated Solar Energy Development Fund to mitigate risks associated with solar energy and buy down the up-front costs of solar energy. ADB aims to raise $ 500 million (€ 385 million) and design innovative financing mechanisms in order to encourage commercial banks and the private sector to invest in solar energy technologies and projects.

2.1.1 Australia

In 2011, 837 MW of new solar photovoltaic electricity systems were installed in Australia, bringing the cumulative installed capacity of grid-connected PV systems to 1.4 GW [Apv 2012]. PV electricity systems accounted for 36 % of all new electricity generation capacity installed in 2011. Like in 2010, the market was dominated by grid connected systems which accounted for 91 % of the new PV installations. The average PV system price for a grid connected system fell from 6 AUD/Wp (4.29 €/Wp[4]) in 2010 to 3.9 AUD/Wp (3 €/Wp[5]) in 2011 and the cost of PV generated electricity has reached the rate residents are paying in many parts of the country.

Most installations took advantage of the incentives under the Australian Government's Renewable Energy Target (RET) mechanisms and feed-in tariffs in some States or Territories. At the beginning of 2011, eight out of the eleven Australian Federal States and Territories had introduced eleven different kinds of feed-in tariff schemes, mainly for systems smaller than 10 kWp. All except three of these schemes had built-in caps which were partly reached that year so that in 2012 only six schemes are still available for new installations and additional changes are expected in the course of this year.

2.1.3 India

For 2011, market estimates for solar PV systems vary between 300 and 350 MW, and for the first time the most of these capacities were grid connected. The Indian Jawaharla Nehru National Solar Mission (JJNSM) was launched in January 2010, and it was hoped that it would give impetus to the grid-connected market. After only a few MW were installed in 2010, installations in 2011 slowly picked up, but the majority of the JJNSM projects will come on-line from 2015 onwards. In June 2012, grid connected PV capacity exceeded 1 GW with Gujarat leading the way with about 65 % [Pvm 2012].

The National Solar Mission aims to make India a global leader in solar energy and envisages an installed solar generation capacity of 20 GW by 2020, 100 GW by 2030 and 200 GW by 2050. The short-term outlook up until 2013 was improved as well when the original 50 MW grid-connected PV system target in 2012 was changed to 1,000 MW for 2013.

2.1.4 Israel

Three years after the introduction of a feed-in tariff in 2008, Israel's grid-connected PV market saw about 130 MW of capacity newly connected in 2011. One of the main drives behind the development of solar energy is energy-security,

[3] Exchange rate: 1 € = 1.30 $

[4] Average Exchange rate 2010: 1 € = 1.40 AUD

[5] Average Exchange rate 2011: 1 € = 1.30 AUD

and it is planned to have about 1 GW of solar PV systems by the end of 2014. In August 2012, about 215 MW have been built and a further 300 MW approved [Blo 2012a]. The approved feed-in tariffs depend on the system size segment and have individual caps.

2.1.4 Japan

In 2011, the Japanese market experienced a moderate growth, increasing its volume to 1.3 GW, bringing the cumulative installed PV capacity to 4.9 GW. In the first half of 2012, about 840 MW of PV systems were installed, which is 50% more than in the same time in 2011.

The consequence of the accident at the Fukujima Daiichi Nuclear Power Plant, in March 2011, was the reshaping of the country's energy strategy. For PV power, an official target of 28 GW was set for 2020. In July 2012, a Ministry for Economy, Trade and Industry (METI) panel proposed the long-awaited plan to reform the country's power market. The plan targets to increase renewable power supply from the 2011 level of 11% to 25% to 35% by 2030.

Until 2010, residential roof-top PV systems represented about 95% of the Japanese market. In 2011, due to a change in permitting, large ground-mounted systems, as well as large commercial and industrial roof-top systems, increased their market share to about 20%.

In June 2012, METI finally issued the Ministerial Ordinances for the new feed-in tariffs for renewable energy sources. The tariff for commercial installations (total generated power) larger than 10kWp is ¥ 40 per kWh for 20 years and ¥ 42 per kWh for residential installations (surplus power) smaller than 10 kWp for 10 years starting from 1 July 2012 until 31 March 2013 [Ikk 2012].

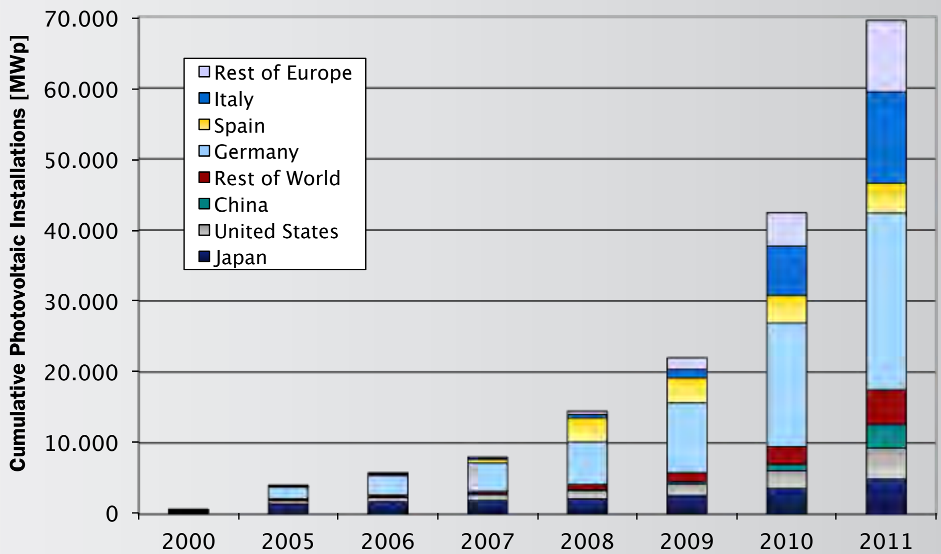
2.1.5 People's Republic of China

The 2011 Chinese PV market grew to 2.5 GW, bringing the cumulative installed capacity to about 3.3 GW [IEA 2012a]. This is a 400% growth compared to 2010, but still only 13% of the total Chinese photovoltaic production. A further increase can be expected due to the recent change of the target for 2015, which was increased to 21 GW by the National Energy Administration (NEA) [Reu 2012].

According to the 12th Five-Year Plan, which was adopted on 14 March 2011, China intends to cut its carbon footprint and become more energy efficient. The targets are 17% less carbon dioxide emissions and 16% less energy consumption unit of GDP. The total investment in the power sector under the 12th Five-Year Plan is expected to reach $803 billion (€ 618 billion), divided into $416 billion (€320 billion), or 52%, for power generation, and $ 386 billion (€ 298 billion) to construct new transmission lines and other improvements to China's electrical grid.

On 24 February 2012, the Chinese Ministry of Industry and Information Technology published its industrial restructuring and upgrading plan (2011-2015) for the photovoltaic industry [MII 2012]. In this document the ministry outlined, that by 2015 it expects only to support "backbone" enterprises, which should produce a minimum of 50,000 MT polysilicon, or 5 GW of solar cell or module production. The plan also projects a cost reduction of electricity generated

Fig. 3: Cumulative Photovoltaic Installations from 2000 to 2011 (data source: EPIA [Epi 2012], Eurobserver [Sys 2012] and own analysis)



with PV systems to 0.8 CNY/kWh (0.098 €/kWh[6]) by 2015 and 0.06 CNY/kWh (0.074 €/kWh) by 2020.

In August 2012, the National Energy Administration (NEA) released the new renewable energy five-year plan for 2011 to 2015 [NEA 2012]. The new goal of NEA calls for renewable energy to supply 11.4% of the total energy mix by 2015. To achieve this goal, the renewable power generation capacity has to be increased to 424 GW. Hydro-power is the main source, with 290 GW including 30 GW pumped storage, followed by wind with 100 GW, solar with 21 GW and biomass with 13 GW.

The plan estimates new investments in renewable energy of CNY 1.8 trillion (€222 billion) between 2011 and 2015. China aims to add a total of 160 GW of new renewable energy capacity during the period 2011-15, namely 61 GW hydro, 70 GW wind, 21 GW solar (10 GW small distributed PV, 10 GW utility scale PV and 1 GW solar thermal power), and 7.5 GW biomass. For 2020, the targets have been increased, as well, and are now a 200 GW for wind, 50 GW for solar (27 GW small distributed PV, 20 GW utility-scale PV and 3 GW solar thermal power) and 30 GW for biomass.

The investment figures necessary are in-line with a World Bank report stating that China needs an additional investment of $64 billion (€49.2 billion) annually over the next two decades to implement an "energy-smart" growth strategy [WoB 2010]. However, the reductions in fuel costs through energy savings could largely pay for the additional investment costs according to the report. At a discount rate of 10%, the annual net present value (NPV) of the fuel cost savings from 2010 to 2030 would amount to $145 billion (€111.5 billion), which is about $70 billion (€53.8 billion) more than the annual NPV of the additional investment costs required.

2.1.6 South Korea

In 2011, about 157 MW of new PV systems were installed in South Korea, about the same as the year before, bringing the cumulative capacity to a total of 812 MW. Since January 2012, Korea's Renewable Portfolio Standard (RPS), officially replaced the feed-in tariffs. For 2012, a solar installation RPS target of 220 MW was set, which is well below the actual installed capacity and the gradual increases to 1.2 GW in 2015. The average spot market value of the Renewable Energy Certificates (RECs) for solar was about 165,000 KRW/MWh (116.5 €/MWh[7]). Depending on the type of solar installation, the RECs are then multiplied by a REC multiplier, varying between 0.7 for ground-mounted free-field systems to 1.5 for building-adapted systems.

The new Renewable Portfolio Standard (RPS) Programme obliges power companies, with at least 500 MW of power capacity, to increase their renewable energy mix from at least 2% in 2012 to 10% by 2022. The renewable energy mix in the Korean RPS is defined as the proportion of renewable electricity generation to the total non-renewable electricity generation.

2.1.7 Taiwan

In June 2009, the Taiwan Legislative Yuan gave its final approval to the Renewable Energy Development Act, a move that is expected to bolster the development of Taiwan's green energy industry. The new law authorises the government to enhance incentives for the development of renewable energy via a variety of methods, including the acquisition mechanism, incentives for demonstration projects and the loosening of regulatory restrictions. The goal is to increase Taiwan's renewable energy generation capacity by 6.5 GW to a total of 10 GW within 20 years. In February 2012, the Ministry of Economic Affairs (MOEA),announced the new feed-in tariffs for 2012. To account for the continuing price reduction of systems, it was split into tariffs for January to June, and July to December. The reduction compared to 2011 for the first half of the year was between 5.5% and 8.3%, with an additional reduction of 7.8% to 10.3% for the tariffs in the second half.

Despite the favourable feed-in tariff, the total installed capacity at the end of 2011 was only between 90 and 100 MW, and the annual installation of about 70 MW was just 1.6% of the 4.3 GW solar cell production in Taiwan that year.

2.1.8 Thailand

Thailand enacted a 15-year Renewable Energy Development Plan (REDP) in early 2009, setting the target to increase the Renewable Energy share to 20% of final energy consumption of the country in 2022. Besides a range of tax incentives, solar photovoltaic electricity systems are eligible for a feed-in premium or "Adder" for a period of 10 years. The original 8 THB[8]/kWh (0.182 €/kWh) "Adder" (facilities in the three southern provinces, and those replacing diesel systems, are eligible for an additional 1.5 THB/kWh (0.034 €/kWh)) was reduced to 6.5 THB/kWh (0.148 €/kWh) for those projects not approved before 28 June 2010. The original cap of 500 MW was increased to 2 GW at the beginning of 2012, due to the high over-subscription of the original target. At the end of 2011, out of the about 150 MW, including 30 MW, off-grid systems were installed. In June 2012, PV projects with about 500 to 600 MW were in their development phase and another 1.5 GW in the PPA application phase.

[6] Exchange Rate 2012: 1 € = 8.1 CNY

[7] Exchange Rate 1 € = 1,420 KRW

[8] Exchange Rate 1 € = 44 THB

2.1.9 Emerging Markets

- **Bangladesh:** In 1997, the Government of Bangladesh established the Infrastructure Development Company Limited (IDCOL) to promote economic development in Bangladesh. In 2003, IDCOL started its Solar Energy Programme to promote the dissemination of solar home systems (SHS) in the remote rural areas of Bangladesh, with the financial support from the World Bank, the Global Environment Facility (GEF), the German Kreditanstalt für Wiederaufbau (KfW), the German Technical Cooperation (GTZ), the Asian Development Bank and the Islamic Development Bank. Since the start of the programme, more than 1.4 million SHS, with an estimated capacity of 90 MW, have been installed in Bangladesh by June 2012 [WoB 2012]. According to media reports, every month about 50,000 additional households are added [Unb 2012].

  In 2011, the Asian Development Bank (ADB) has agreed to provide financial support to Bangladesh for implementing the installation of 500 MW within the framework of the Asian Solar Energy Initiative [Dai 2011, Unb 2011].

- **Indonesia:** The development of renewable energy is regulated in the context of the national energy policy by Presidential Regulation No. 5/2006 [RoI 2006]. The decree states that 11% of the national primary energy mix in 2025 should come from renewable energy sources. The target for solar PV is 1000 MW by 2025. At the end of 2011 about 20 MW of solar PV systems were installed, mainly for rural electrification purposes.

- **Malaysia:** The Malaysia Building Integrated Photovoltaic (BIPV) Technology Application Project was initiated in 2000 and at the end of 2009 a cumulative capacity of about 1 MW of grid-connected PV systems installed. The Malaysian Government officially launched their GREEN Technology Policy in July 2009 to encourage and promote the use of renewable energy for Malaysia's future sustainable development. By 2015, about 1 GW must come from Renewable Energy Sources according to the Ministry of Energy, Green Technology and Water (KETHHA).

  In April 2011, renewable energy feed-in tariffs were passed by the Malaysian Parliament. The 2012 tariffs were set by the Sustainable Energy Development Authority (SEDA) between 0.85 and 1.23 MRY/kWh (0.22 to 0.31 €/kWh[9]), depending on the system size. There are a number of add-ons depending on the use in buildings, or local content. For the next two years, an annual digression of the tariffs, by about 9% annually, is foreseen. As of August 2012, about 0.5 MW of PV systems, under the new FiT scheme, are already connected and another 166 MW have received approval, and are in various stages of project planning or installation.

  First Solar (USA), Q Cells (Germany) and Sunpower (USA) have set up manufacturing plants in Malaysia, with a total investment of RM 12 billion and more than 2 GW of production capacities. Once fully operational, these plants will provide 11,000 jobs and Malaysia will be the world's sixth largest producer of solar cells and modules.

- **The Philippines:** The Renewable Energy Law was passed in December 2008 [RoP 2008]. Under the Law, the Philippines has to double the energy derived from Renewable Energy Sources within 10 years.
  On 14 June 2011, Energy Secretary, Rene Almendras unveiled the new Renewable Energy Roadmap, which aims to increase the share of renewables to 50% by 2030. The programme will endeavour to boost renewable energy capacity from the current 5.4 GW to 15.4 GW by 2030.
  Early 2011, the country's Energy Regulator National Renewable Energy Board (NREB) has recommended a target of 100 MW of solar installations that will be constructed in the country over the next three years. A feed-in tariff of 17.95 PHP/kWh (0.299 €/kWh)[10] was suggested, to be paid from January 2012 onwards. For 2013 and 2014, an annual degression of 6% was foreseen. The initial period of the programme is scheduled to end on 31 December 2014.
  On 27 July 2012, the Energy Regulatory Commission decided to lower the tariff in view of lower system prices to 9.68 PHP/kWh (0.183 €/kWh[11]) and confirmed the degression rate.
  At the end of 2011, about 12 MW of PV systems were installed, mainly off-grid.

  SunPower had two cell manufacturing plants outside of Manila, but decided to close down Fab. No 1 early 2012. Fab. No 1 had a nameplate capacity of 125 MW and Fab. No 2 has another nameplate capacity of 575 MW.

- **Vietnam:** In December 2007, the National Energy Development Strategy of Vietnam was approved. It gives priority to the development of renewable energy and includes the following targets: increase the share of

[9] Exchange rate: 1 € = 3,90 MYR
[10] Exchange Rate 2011 1 € = 60 PHP
[11] Exchange Rate 2012 1 € = 53 PHP

renewable energies from negligible to about 3% (58.6 GJ) of the total commercial primary energy in 2010, to 5% in 2020, 8% (376.8 GJ) in 2025, and 11% (1.5 TJ) in 2050. At the end of 2011, about 5 MW of PV systems were installed, mainly in off-grid applications. The Indo-Chinese Energy Company (IC Energy) broke ground for the construction of a thin-film solar panel factory with an initial capacity of 30 MW and a final capacity of 120 MW in the central coastal Province of Quang Nam on 14 May 2011. However, in June 2012, the company applied for the permission to delay the project with no new date set.
In March 2011, First Solar broke ground on its four-line photovoltaic module manufacturing plant (250 MW) in the Dong Nam Industrial Park near Ho Chi Minh City, but decided early 2012 to put the facility up for sale.

2.2 Europe and Turkey

Market conditions for photovoltaics differ substantially from country to country. This is due to different energy policies and public support programmes for renewable energies and especially photovoltaics, as well as the varying grades of liberalisation of domestic electricity markets. Within one decade, the solar photovoltaic electricity generation capacity has increased 280 times from 185 MW in 2000 to 52 GW at the end of 2011 (Fig. 4) [Epi 2012, Sys 2012].

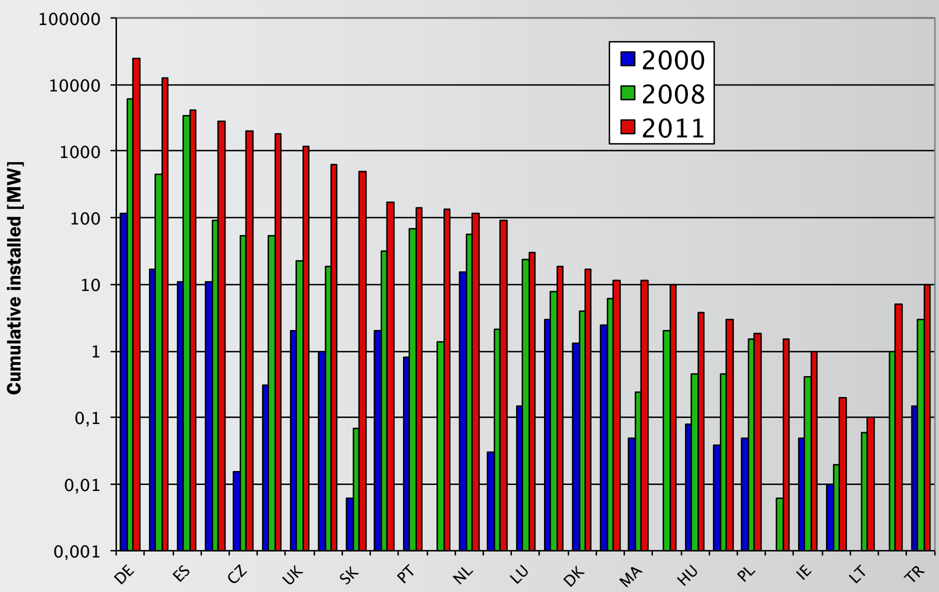
A total of about 46.1 GW of new power capacity was connected in the EU last year and 7.8 GW were decommissioned, resulting in 38.3 GW of new net capacity (Fig. 5) [Ewe 2011, Sys 2011]. Photovoltaic electricity generation capacity accounted for 21.5 GW[12], or 56% of the new net capacity. In terms of new net capacity, wind power moved to the second place with 9.4 GW (25%), followed by 8.8 GW (23%) gas-fired power stations; 3.1 GW (8%) MW coal-fired power stations; 590 MW (1.5%) hydro, 470 MW (1.2%) CSP, 170 MW (> 1%) biomass; and 70 MW (> 1%) waste. The net installation capacity for oil-fired and nuclear power plants was negative, with a decrease of 447 MW and 5.9 GW respectively. The renewable share of new power installations was more than 65% and more than 76% of new net capacity in 2011.

In the following sub-chapters, the market development in some of the EU Member States, as well as Switzerland and Turkey, is described.

2.2.1 Belgium

Belgium showed another strong market performance year in 2011, with new photovoltaic system installations of 775 MW bringing the cumulative installed capacity to 1812 MW. However, most of the installations were done in Flanders, where, since 1 January 2006, Green Certificates exist for 20 years. In 2011, the value of the certificates decreased from 0.33 €/kWh (January to June) to 0.30 €/kWh (July to September) and 0.27 €/kWh (October to December). For 2012, the price decreases every four months by two Eurocents. In Wallonia, the Green Certificates have a guaranteed minimum price between 0.15 – 0.462 €/kWh, depending on the size of the systems and region (Wallonia 15 years).

Fig. 4: Cumulative installed grid-connected PV capacity in EU + CC
Note that the installed capacities do not correlate with solar resources.



[12] The new connected PV capacity in 2011 includes those PV plants, which were already built in 2010, but not yet connected to the grid (mainly in Italy). Therefore, there is a difference of about 3 GW between the installation figures and the connection figures.

2.2.2 Bulgaria
In May 2011, a new Renewable Energy Source (RES) Act was approved. The new law fixed the FIT levels and this resulted in new installations of around 110 MW, increasing the total installed capacity to 134 MW at the end of 2011. Up until the end of July 2012, about 600 MW of PV systems were cumulatively installed.

In March 2012, the Bulgarian Parliament voted on the revision of the RES Act, which was then published in the State Gazette in April [GoB 2012]. The most significant change is that the price at which electricity will be purchased is no longer fixed at the date when the installation is completed, but at the date the usage permit is granted.

On 1 June 2012, new feed-in tariffs went into force, which correspond to a 34 to 54% reduction, depending on the system type. In July 2012, the Bulgarian Energy Regulator (SEWRC) proposed a further reduction, ranging between 5 and 35%.

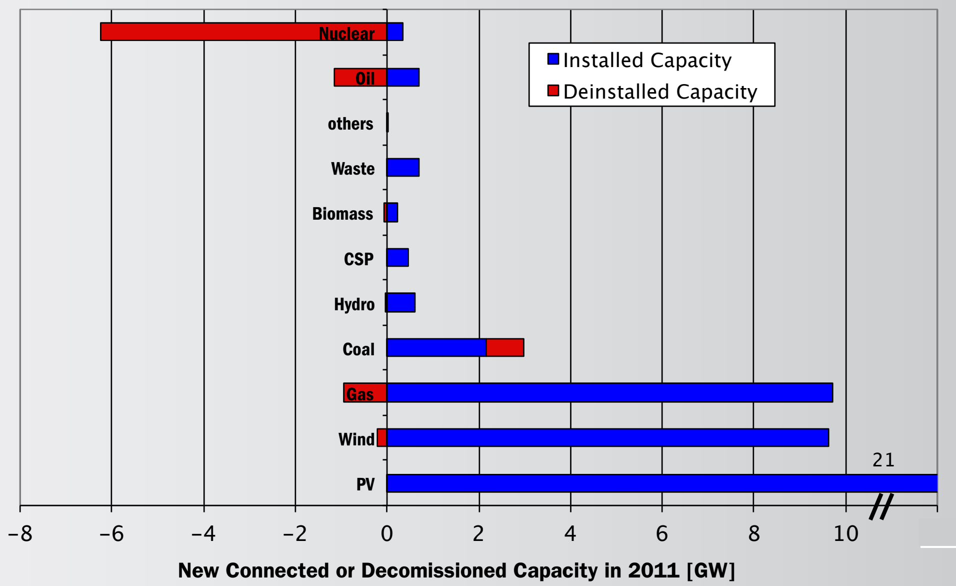
2.2.3 France
In 2011, 1.63 GW of PV systems were connected to the grid in France, with a significant part of the systems already installed in 2010. This led to an increase of the cumulative installed capacity to 2.83 GW, including about 300 MW in the French Overseas Departments. Smaller decentralised systems are about 2.3 GW and larger solar farms are around 0.5 GW..

This rapid growth led to a revision of the feed-in scheme in February 2011, setting a cap of 500 MW for 2011 and 800 MW for 2012 [MEI 2011]. The 2011 tariff levels only applied to rooftop systems up to 100 kW in size. In addition, those installations were divided into three different categories: residential; education or health; and other buildings with different feed-in tariffs, depending on the size and type of installation. The tariffs for these installations ranged between 0.2883 €/kWh and 0.46 €/kWh. All other installations up to 12 MW were just eligible for a tariff of 0.12 €/kWh. The feed-in tariffs decreased by 10% on 1 January 2012 and a second decrease ranging between 2.6 and 9.5%, depending on the type of installation took place on 1 April. At the moment, France has three different support schemes for PV. For systems up to 100 kWp, there is the feed-in tariff, for rooftop systems between 100 and 250 kWp a “simplified” call for tender with a 300 MW cap for 2012 and for systems larger than 250 kWp (large rooftop and ground mount systems) the “ordinary” call for tender with a 450 MW cap.

Between March 2011 and March 2012, the regional distribution companies received applications worth 640 MW for new photovoltaic installations up to 100 kW in size, according to the French Energy Regulator CRE (Commission de Regulation de l’Energie). This was more than three times the target the government announced in 2011 for that market segment.

2.2.4 Germany
Germany had even a slight increase compared to 2010, from 7.4 GW to 7.5 GW [Bun 2012]. The German market growth is directly correlated to the introduction of the Renewable Energy Sources Act or *“Erneuerbare Energien*

Fig. 5: New installed or decommissioned electricity generation capacity in Europe in 2011



Gesetz" (EEG) in 2000 [EEG 2000]. This Law introduced a guaranteed feed-in tariff for electricity generated from solar photovoltaic systems for 20 years and already had a fixed built-in annual decrease, which was adjusted over time to reflect the rapid growth of the market and the corresponding price reductions. Due to the fact that until 2008 only estimates of the installed capacity existed, a plant registrar was introduced from 1 January 2009 on.

The German market had a strong performance throughout the year with an extraordinary peak in December, when almost 3 GW were installed just before the scheduled tariff reduction of 15% on 1 January 2012. Compared to 2009, the feed-in tariffs have been reduced by 43 to 46% depending on the system size and classification. In August 2012 the Bundesnetzagentur (German Federal Network Agency) announced that almost 4.4 GW of new systems had been installed in the first half of 2012, bringing the total capacity to 29.2 GW.

2.2.5 Greece

Greece introduced a new feed-in tariff scheme on 15 January 2009. The tariffs remained unchanged until August 2010 and are guaranteed for 20 years. However, if a grid-connection agreement was signed before that date, the unchanged FIT was applied if the system is finalised within the next 18 months. For small rooftop PV systems, an additional programme was introduced in Greece on 4 June 2009. This programme covers rooftop PV systems up to 10 kWp (both for residential users and small companies). In 2011, the tariffs for PV systems, with the exception of small rooftop systems (<10 kWp) decreased in February by 5% and August by 6%. Despite the severe financial crisis, it is remarkable that 426 MW of new installations were carried out, bringing the total capacity to about 631MW in 2011. In view of the reduced system prices, the feed-in tariff for 2012 was lowered in February by 11% for small rooftop systems and 20% for all others. The changes in August were more drastic, with a tariff reduction of almost 50% to 0.25 €/kWh for small rooftop systems, 31% to 0.225 €/kWp for systems up to 100 kWp and 28% to 0.18 €/kWh for systems larger than 100 kWp.

2.2.6 Italy

Italy connected most new PV capacity with 9.1 GW, but this includes about 3.2 GW of PV systems, which were reported under the second "conto energia" and probably already installed, but not yet connected in 2010. In terms of new installations, Italy added a capacity of about 5.9 GW, bringing cumulative installed capacity to 12.8 GW at the end of 2011 [Ges 2012]. At the End of August 2012, the total connected PV capacity has surpassed 14.9 GW [Gse 2012a].

The *Quinto Conto Energia* (Fifth Energy Bill) was approved by the Italian Council of Ministers on 5 July 2012 [Gaz 2012]. The Bill set the new half yearly reductions of the tariffs, and the annual expenditure ceiling for new installations has been increased from €500 million to €700 million. The 2012 ceiling is €6.7 billion, but at the end of August already €6.2 to 6.3 billion have been allocated. In addition, a new requirement to register systems larger than 12 kWp was introduced. The new tariffs, valid from 27 August 2012, are between 13 and 21% lower than in the first half of the year and between 6 and 13% more than the reduction foreseen back in 2011.

2.2.7 Slovakia

In 2011, Slovakia experienced a rapid growth of PV system installations, with a more than doubling of the annual installations to 314 MW, mainly ground mounted systems. Cumulative installed capacity was 488 MW at the end of 2011. This is already three times the original 160 MW capacity target for 2020, published in the National Renewable Energy Action Plan in 2010. From February 2011, the support was limited to applications for systems smaller than 100 kW and after a reduction of the feed-in tariff by 35% mid 2011, the tariff has been reduced by 25% from 1 January 2012 on.

2.2.8 Spain

Spain is still third in Europe regarding the total cumulative installed capacity with 4.2 GW. Most of this capacity was installed in 2008 when the country was the biggest market, with close to 2.7 GW in 2008 [Epi 2012]. This was more than twice the expected capacity and was due to an exceptional race to install systems before the Spanish Government introduced a cap of 500 MW on the yearly installations in the autumn of 2008. A revised Decree (Royal Decree 1758/2008) set considerably lower feed-in tariffs for new systems and limited the annual market to 500 MW, with the provision that two thirds are rooftop mounted and no longer free-field systems. These changes resulted in a new installed capacity of about 20 MW in 2009, 370 MW in 2010 and 350 MW in 2011.

In May 2012, electricity generated with solar PV systems accounted for 4.5% of Spain's total electricity demand, according to the grid operator Red Eléctrica de Espana.

In January 2012, the Spanish Government passed the Royal Decree 1/12 [GoS 2012], which suspended the remuneration pre-assignment procedures for new renewable energy power capacity, affecting about 550 MW of planned solar PV installations. The justification given for this move is the fact that Spain's energy system has over time amassed a €25 billion power-tariff deficit and it is argued that the special regime for renewable energy is the main reason. However, for over a decade, the Spanish Government has prevented utilities from charging consumers the true costs of electricity. Instead of allowing utilities to increase rates every time electricity generation costs increased (due to rising coal or natural gas costs, inflation, or to changes in energy or environmental policy), the government allowed them to create a scheme like a deferral account whereby they could recover shortfalls in any individual year from revenues generated in subsequent years.

Already in January 2007, the European Commission opened an in-depth investigation to examine the potential aid to large and medium-sized companies and to electricity distributors in Spain, in the form of artificially low regulated industrial tariffs for electricity [EC 2007]. In 2005, these regulated tariffs led to a deficit of €3.8 billion in the Spanish electricity system which amounted to almost €9 billion in 2007, a time when payments under the special regime for renewable energy were still limited.

2.2.9 Switzerland

In 2011 100 MW of PV systems have been installed in Switzerland, almost doubling the total capacity to 211 MW. In addition, there is a waiting list with a total capacity of about 460 MW. In view of the decreasing PV system prices, two feed-in tariff reductions were scheduled in Switzerland. The first took place on 1 March 2012, with a 15 to 18% reduction and another 8 to 10% reduction is scheduled for 1 October 2012.

2.2.10 United Kingdom

The United Kingdom introduced a new feed-in tariff scheme in 2010, which led to the installation of approximately 55 MW, bringing the cumulative installed capacity to about 85 MW. The announcement of a fast-track review of large scale projects by the Department of Energy & Climate Change (DECC) in February 2012, led to a rush to complete those projects in the first half of 2011 [DEC 2011]. For systems larger than 50 kWp, the tariffs were reduced by 42% up to 72%. A second rush occurred towards the end of the year to meet the deadline of 12 December 2011, when DECC planned to decrease the residential tariff by about 50%, as a result of another fast-track consultation. However, this decision was contested in court and the tariffs were only changed on 1 April 2012. The average reductions in April were 44 to 54% for systems smaller than 50 kWp and 0 to 32% for systems above 50 kWp. For 1 November 2012, a further reduction of 3.5% for systems smaller 50 kWp is foreseen, whereas no reduction will be done for larger systems, due to the fact that almost no such systems have been installed between May and July 2012.

1.2.11 Other European Countries and Turkey

After two years with high growth rates, the PV market in the **Czech Republic** stalled due to a number of legislative changes which took place in the second half of 2010. They resulted in lower feed-in tariffs, the phase-out of ground-mounted PV systems from 1 March 2011 onwards and the introduction of a retroactive tax on benefits generated by PV installations. Despite the fact that the grid freeze had been lifted at the beginning of 2012, CEPS, the high grid voltage operator imposed a limit of 65 MW for new solar and wind installations, with a case-by case assessment of the individual projects.

Despite high solar radiation, solar photovoltaic system installation in **Portugal** has only grown very slowly and reached a cumulative capacity of 130 MW at the end of 2010.

In **Turkey** during March 2010, the Energy Ministry unveiled its 2010 – 2014 Strategic Energy Plan. One of the government's priorities is to increase the ratio of renewable energy resources to 30% of total energy generation by 2023. At the beginning of 2011, the Turkish Parliament passed a Renewable Energy Legislation which defines new guidelines for feed-in tariffs. The feed-in tariff is 0.133 $/kWh (0.10 €/kWh) for owners commissioning a PV system before the end of 2015. If components 'Made in Turkey' are used, the tariff will increase by up to $0.067 (€0.052), depending on the material mix. Feed-in tariffs apply to all types of PV installations, but large PV power plants will receive subsidies up to a maximum size of 600 MWp. At the beginning of 2012, about 10 MW of PV systems were installed, with a target of 3 GW set for 2023.

Ukraine saw an impressive growth, with almost 200 MW, thanks to the development of two very large power plants developed by one company. In July 2012, the Ukrainian Parliament had the first reading of a bill to simplify the access of households to the feed-in scheme. At the same time, it proposed a reduction in the feed-in tariff between 16 and 27%, depending on the kind of installation.

2.3 Africa

Despite the vast solar resources and the fact that there are areas in Africa where solar potential can be considered very interesting, with the same photovoltaic panel ready to produce twice as much electricity in Africa as in Central Europe on average, only limited use of solar photovoltaic electricity generation is made. The main application for PV systems in Africa are small solar home systems and the market statistics for these are extremely imprecise or non-existent. Therefore, all African countries are **potential or emerging markets** and some of them are mentioned below.

Capo Verde's Renewable Energy Plan (2010 to 2020) aims to increase the use of renewable energy to 50% in 2020. The policy to achieve this is to use PPA. **Law n1/2011** establishes the regulations regarding the independent energy production. In particular, it establishes the framework conditions for the set up of Independent Power Producers using renewable energy (15 years PPA), and for the self production at user level. It creates the micro-generation regime and regulates rural electrification projects and states the tax exemption of all imported RE equipment. At the end of 2011, 7.5 MW of centralised grid-connected PV systems were installed. In addition, there are a number of smaller off-grid and grid-connected systems. To realise the 2020 50% Renewable energy target, about 340 MW of PV systems are required.

In 2008, **Kenya** introduced feed-in tariffs for electricity from renewable energy sources, but solar was only included in the revision dated 2010 [GoK 2010]. However, only a little more than 560 kW of PV capacity was connected to the grid in 2011. The majority of the 14 MW of PV systems were off-grid installations.

The **Kingdom of Morocco's** solar plan was introduced in November 2009, with the aim of establishing 2,000MW of solar power by 2020. To implement this plan, the Moroccan Agency for Solar Energy (MASEN) was founded in 2010. Both solar electricity technologies, Concentrating Solar Thermal Power (CSP) and PV will openly compete. Already in 2007, the National Office of Electricity (ONE) announced a smaller programme for grid-connected distributed solar PV electricity, targeting 150 MW of solar PV power. Various rural electrification programmes using PV systems have been ongoing for a long time. At the end of 2011, Morocco had about 20 MW of PV systems installed, mainly under the Global Rural Electrification Programme (PERG) Framework and about 1 to 2 MW grid-connected systems.

South Africa has a fast increasing electricity demand and vast solar resources. In 2008, the country enacted its National Energy Act, which calls for a diversification of energy sources, including renewables, as well as fuel switching to improve energy efficiency [GoS 2008]. The South African Renewables Initiative, under discussion in 2012, calls for 13.2 GW of PV systems installed by 2025. However, the projected installation costs of $10 billion (€7.7 billion) for 2 GW between the time-frame of 2013 to 2017, are extremely high, considering that on average the PV Project Apex was between $1.6 and 1.7 million (€1.23 to 1.3 million) per MW in the second quarter of 2012 [Blo 2012b]. In 2011, the Renewable Energy Independent Power Producer Procurement Programme (IPP) was set up with five biddings (one in 2011, two in 2012 and two in 2013) planned until 2013. The overall target is 3.725 GW and the one for solar photovoltaic is 1.45 GW. In the first two bidding rounds 1,048 MW of solar PV projects were already allocated to the preferred bidders. The average bid price changed between the first round (closure date: 4 November 2011) from 2.65 ZAR/kWh (0.252 €/kWh) to 1.65 ZAR/kWh (0.157 €/kWh) in the second round (closure date: 5 March 2012). However, it is still unclear when those projects will be connected to the grid. At the end of 2011, about 40 to 50 MW of PV systems were installed in South Africa.

2.4 Americas

2.4.1 Canada

In 2011, Canada almost doubled its cumulative installed PV capacity to about 570 MW, with 268 MW new installed systems. This development was driven by the introduction of a feed-in tariff in the Province of Ontario, enabled by the *"Bill 150, Green Energy and Green Economy Act, 2009"*. Ontario accounted for over 90% of all new installations. On the Federal level, only an accelerated capital cost allowance exists under the Income Tax Regulations. On a Province level, nine Canadian Provinces have *Net Metering Rules,* with solar photovoltaic electricity as one of the eligible technologies, *Sales Tax Exemptions* and *Renewable Energy Funds* exist in two Provinces and *Micro Grid Regulations* and *Minimum Purchase Prices* each exist in one Province.

The Ontario feed-in tariffs were set in 2009, depending on the system size and type and were reduced in various steps between 21 and 32%. On 5 April they were set as follows:

- Rooftop ≤ 10 kW
  54.9 ¢/kWh (0.422 €/kWh[13])
- Rooftop > 10 kW ≤ 100 kW
  54.8 ¢/kWh (0.422 €/kWh)
- Rooftop > 100 kW ≤ 500 kW
  53.9 ¢/kWh (0.415 €/kWh)
- Rooftop > 500 kW
  48.7 ¢/kWh (0.375 €/kWh)
- Ground-mounted[14] ≤ 10 kW
  44.5 ¢/kWh (0.34.2 €/kWh)
- Ground-mounted > 10 kW ≤ 500 kW
  38.8 ¢/kWh (0.298 €/kWh)
- Ground-mounted > 500 kW
  35.0 ¢/kWh (0.269 €/kWh)
- Ground-mounted* >10 kW ≤ 10 MW
  34.7 ¢/kWh (0.267 €/kWh)

The feed-in tariff scheme has a number of special rules, ranging from eligibility criteria, which limit the installation of ground-mounted PV systems on high-yield agricultural land to domestic content requirements and additional "price adders" for Aboriginal and community-based projects. Details can be found in the Feed-in Tariff Programme of the Ontario Power Authority [Ont 2012].

2.4.2 United States of America

With over 1.8 GW of newly installed PV capacity, the USA reached a cumulative PV capacity of almost 4.4 GW at the end of 2011. Utility PV installations again more than tripled, compared to 2010 and reached 754 MW in 2011. The top ten States - California, New Jersey, Arizona, New Mexico, Colorado, Pennsylvania, New York, North Carolina, Texas and Nevada, accounted for more than 87 % of the US PV market [Sei 2012].

PV projects with Power Purchase Agreements (PPAs), with a total capacity of 9 GW, are already under contract and to be completed by 2016. Over 3 GW of these projects are already financed and under construction [Sei 2012]. If one adds the over 30 GW of projects in an earlier planning stage, which are actively seeking permits, interconnection agreements, PPAs and finance, the pipeline stands at 39 GW.

Many State and Federal policies and programmes have been adopted to encourage the development of markets for PV and other renewable technologies. These consist of direct legislative mandates (such as renewable content requirements) and financial incentives (such as tax credits). One of the most comprehensive databases, about the different support schemes in the US, is maintained by the Solar Centre of the State University of North Carolina. The Database of State Incentives for Renewable Energy (DSIRE) is a comprehensive source of information on State, local, utility, and selected Federal incentives that promote renewable energy. All the different support schemes are described therein and it is highly recommended to visit the DSIRE web-site www.dsireusa.org/ and the corresponding interactive tables and maps for details.

2.4.3 Emerging markets

In 2006, **Argentina** passed its Electric Energy Law which established that 8 % of the electricity demand should be generated by renewable sources by 2016 [GoA 2006]. The Law also introduced FiTs for wind, biomass, small-scale hydro, tidal, geothermal and solar for a period of 15 years. In July 2010, amongst other renewable energy sources, the Government awarded PPAs to six solar PV projects totalling 20 MW. At the end of 2011, about 10 MW of PV systems were installed. According to the renewable energy country attractiveness indicator, the Argentinean Government has set a 3.3 GW target for PV installations by 2020 [Ern 2011].

At the end of 2011, **Brazil** had about 20 MW cumulative installed capacity of PV systems, mainly in rural areas. In April 2012, the board of the National Agency of Electric Energy (ANEEL) approved new rules to reduce barriers to install small distributed generation capacity. The rule applies to generators that use subsidised sources of energy (hydro, solar, biomass, cogeneration and wind). In its mid-term market report, the IEA forecasts a cumulative installed PV capacity of about 100 MW in 2012 and 900 MW by 2017 [IEA 2012].

In February 2012, the President of **Chile**, President Piñera, announced a strategic energy plan how to reach 20 % of non-conventional renewable energy by 2020. Legislation to reach this 20 % renewable energy targets is currently under consideration. In the first quarter of 2012, the first MW size PV system was installed in the northern Atacam desert. Chile's Environmental Assessment Service (SEA) has approved four solar photovoltaic projects, with a total of 506.5 MW in the Antofagasta region, on 20 August 2012. SEA approved the 76.7 MW and 69.8 MW Laberinto Este and Oeste, 180 MW Encuentro Solar and 180 MW Crucero Solar projects.

Already in 2007, the **Dominican Republic** passed a law promoting the use of renewable energy and set a target of 25 % renewable energy share in 2025 [GoD 2007]. At that time about 1 to 2 MW of solar PV systems were installed

[13] Exchange Rate 1 € = 1.30 CAD
[14] Eligible for Aboriginal or community adder

in rural areas, which increased to over 5 MW in 2011. In 2011, when the first PPA for 54 MW was signed between Grupo de Empresas Dominicanas de Energía Renovable and Corporación Dominicana de Empresas Eléctricas Estatales (CDEEE). The first phase (200 kW) of the project became operational in July 2012 and the whole solar farm should be connected to the grid early 2013. In 2012, CDEEE signed two more PPAs with a total capacity of 116 MW.

In 2008, **Mexico** enacted the Law for Renewable Energy Use and Financing Energy Transition to promote the use of renewable energy [GoM 2008]. In 2012, the country passed its Climate Change Law, which foresees a decrease in Greenhouse Gas (GhG) Emissions of 30% below the business-as-usual case by 2020 and 50% by 2050 [GoM 2012]. It further stipulates a share of renewable electricity of 35% by 2024. At the end of 2011, about 37 MW of PV systems were installed according to the IEA PVPS [IEA 2012c]. According to media reports, investments in photovoltaic panel installations have increased by 150%, from $20 to $50 million (€15.4 to 38.5 million) from 2010 to 2011.

In 2008, **Peru** passed the Legislative Decree 1002, which made the development of renewable energy resources a national priority. The decree states that by 2013 at least 5% of electricity should be supplied from renewable sources, such as wind, solar, biomass, and hydro. In February 2010, the Control Agency OSINERGMIN (Organismo Supervisor de la Inversión en Energía y Minería) held the first round of bidding and awarded four solar projects with a total capacity of 80 MW, which should start operation before the end of 2012. A second bidding round was held in 2011, with a quota of 24 MW for PV.

3. The Photovoltaic Industry

In 2011, the photovoltaic world market grew by more than 35% in terms of **production** to about 35 GW. The market for installed systems grew by almost 30% and values between 26 and 28 GW were reported by various consultancies and institutions. This mainly represents the grid-connected photovoltaic market. To what extent the off-grid and consumer-product markets are included is unclear. The difference of roughly 7 to 9 GW has therefore to be explained as a combination of unaccounted off-grid installations (approx. 1-200 MW off-grid rural, approx. 1-200 MW communication/signals, approx. 100 MW off-grid commercial), consumer products (ca. 1-200 MW) and cells/modules in stock.

In addition, the fact that some companies report shipment figures, some report sales figures and others report production figures, add to the uncertainty. An additional uncertainty is the fact that some companies produce sometimes less solar cells than solar modules, but the reporting does not always differentiate between the two and there is a risk that cell production is counted double, first at the cell manufacturer and second at the "integrated" cell/module manufacturer. The difficult economic conditions contributed to the decreased willingness to report confidential company data. Nevertheless, the figures show a significant growth of the production, as well as an increasing installation market.

The announced production capacities, based on a survey of more than 350 companies world-wide increased, even with difficult economic conditions. Despite the fact that about three dozen companies declared bankruptcy, stopped production or announced a scale-back or cancellation of their expansion plans for the time being, the number of new entrants into the field, including some large semiconductor or energy-related companies overcompensated this. At least on paper the expected production capacities are still increasing. Only published announcements of the respective companies and no third source info were used. The cut-off date of the info used was August 2012.

Please note that production capacities are often calculated with different operation parameters such as number of shifts, operating hours per year, etc. In addition, the capacity increase announcements do not always specify when the capacity will be fully ramped up and operational. This method has of course the setback that a) not all companies announce their capacity increases in advance and b) that in times of financial tightening, the announcements of the scale-back of expansion plans are often delayed, in order not to upset financial markets. Therefore, the capacity figures just give a trend, but do not represent final numbers.

If all these ambitious plans can be realised by 2015, China will have about 61.1% of the world-wide production capacity of 119 GW, followed by Taiwan (14.3%), Europe and Japan (5.5%) (Fig. 6).

All these ambitious plans to increase production capacities at such a rapid pace, depend on the expectations that markets will grow accordingly. This, however, is the biggest uncertainty, as the market estimates for 2012 vary between 28 GW and 35 GW. In addition, most markets are still dependent on public support in the form of feed-in tariffs, investment subsidies or tax-breaks.

Already now, electricity production from photovoltaic solar systems has shown that it can be cheaper than peak prices in the electricity exchange. In the second quarter of 2012, the German average price index, for rooftop systems up to 100 kWp, was given with €1,776 per kWp, without tax or just 35% of the price six years ago [Bsw 2012]. With such investment costs, the electricity generation costs are already at the level of residential electricity prices in some countries, depending on the actual electricity price and the local solar radiation level. But only if markets and competition continue to grow, prices of the photovoltaic systems will continue to decrease world-wide and make electricity from PV systems for consumers even cheaper than from conventional sources. Further cost reduction of photovoltaic electricity now depends no longer only on the photovoltaic system components itself, but increasingly on the integration costs into the existing infrastructure. Therefore, to make PV-generated electricity a major source of the world-wide electricity supply for the next decade, more effort has to be focused on optimising the non-PV costs and public support, especially on regulatory measures.

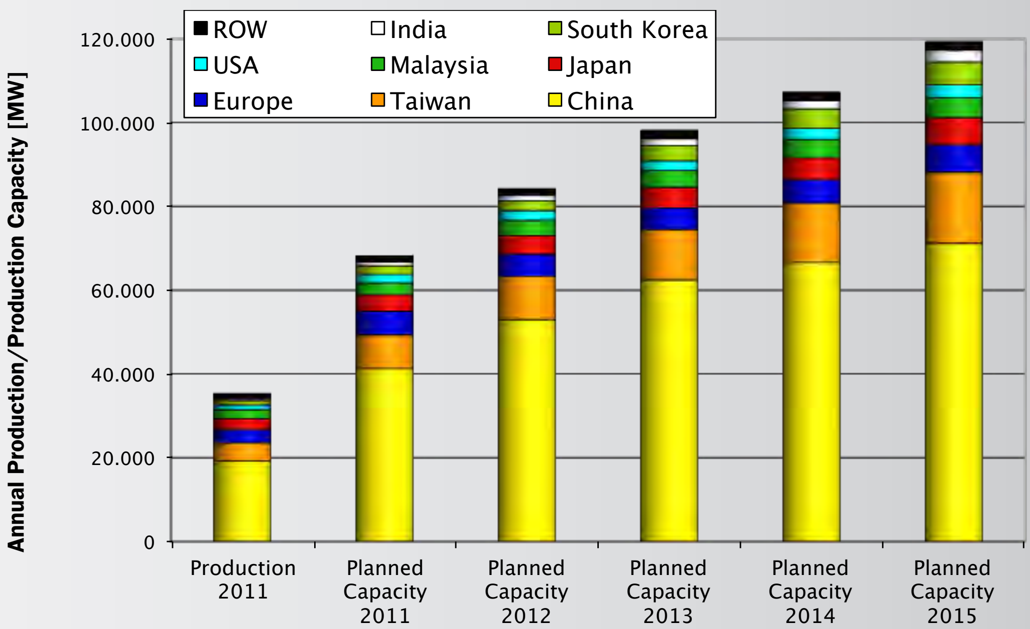
3.1 Technology Mix

As silicon prices fell drastically after the temporary silicon shortage, wafer-based silicon solar cells decreased their cost very rapidly and are still the main technology with around 85% market shares in 2011. Commercial module efficiencies are within a wide range between 12 and 20%, with monocrystalline modules between 14% – 20%, and polycrystalline modules between 12% – 17%. The massive manufacturing capacity increases for both technologies were followed by the necessary capacity expansions for polysilicon raw material.

In 2005, for the first time, production of thin-film solar modules reached more than 100 MW per annum. Between 2005 and 2009, the ***Compound Annual Growth Rate*** (CAGR) of thin-film solar module production was beyond that of the overall industry, increasing the market share of thin-film products from 6% in 2005 to 10% in 2007 and 16 – 20% in 2009. Since then, the thin film share is decreasing slowly as the ramp up of new production lines did not follow that of wafer-based silicon.

More than 200 companies are involved in thin-film solar cell activities, ranging from basic R&D activities to major manufacturing activities and over 120 of them have announced the start or increase of production. The first

Fig. 6: World-wide PV Production 2011 with future planned production capacity increases



100 MW thin-film factories became operational in 2007, followed by the first 1 GW factory in 2010. If all expansion plans are realised in time, thin-film production capacity could be 13 GW, or 15% of the total 80 GW in 2012, and 23 GW, or 19%, in 2015 of a total of 119 GW (Fig. 7).

One should bear in mind that less than 20 companies of the over 120 companies, with announced production plans, have produced thin-film modules of 50 MW, or more in 2011. Another 20 companies filed for insolvency, or announced the termination of their thin-film operations in the last 12 months.

The majority of companies is silicon-based and use either amorphous silicon or an amorphous/microcrystalline silicon structure, followed by companies using Cu(In,Ga)(Se,S)2 as absorber material for their thin-film solar modules, whereas only a few companies use CdTe or dye and other materials.

Concentrating Photovoltaics (CPV) is an emerging technology which is growing at a very high pace, although from a low starting point. About 50 companies are active in the field of CPV development and almost 60% of them were founded in the last six years. Over half of the companies are located either in the United States of America (primarily in California) and Europe (primarily in Spain).

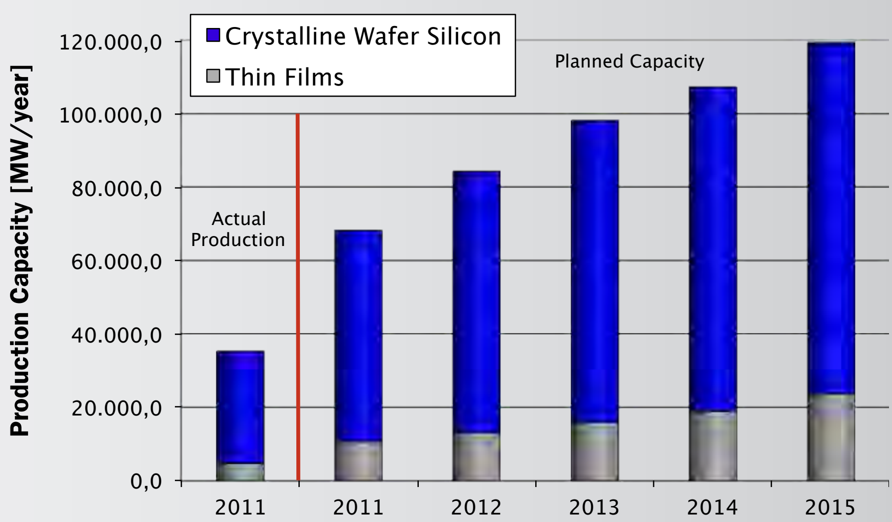
Within CPV there is a differentiation according to the concentration factors[15] and whether the system uses a dish (Dish CPV) or lenses (Lens CPV). The main parts of a CPV system are the cells, the optical elements and the tracking devices. The recent growth in CPV is based on significant improvements in all of these areas, as well as the system integration. However, it should be pointed out that CPV is just at the beginning of an industry learning curve, with a considerable potential for technical and cost improvements. The most challenging task is to become cost-competitive with other PV technologies quickly enough in order to grow to reach factory sizes, which can count on economy of scale.

With market estimates for 2011 in the 60 MW range, and 90 MW under construction in May 2012, the market share of CPV is still small, but analysts forecast an increase to more than 500 MW globally by 2015.

The existing photovoltaic technology mix is a solid foundation for future growth of the sector as a whole. No single technology can satisfy all the different consumer needs, ranging from mobile and consumer applications, with the need for a few watts to multi MW utility-scale power plants. The variety of technologies is an insurance against a roadblock for the implementation of solar photovoltaic electricity, if material limitations or technical obstacles restrict the further growth or development of a single technology pathway.

[15] High concentration > 300 suns (HCPV), medium concentration 5 < x < 300 suns (MCPV), low concentration < 5 suns (LCPV).

Fig. 7: Annual PV Production capacities of Thin-Film and Crystalline Silicon based solar modules.



3.2 Solar Cell Production[16] Companies

World-wide, more than 350 companies produce solar cells. The solar cell industry over the last decade was very dynamic, but the changes which have been happening since 2011 allow only for a snapshot picture of the current situation, which might have changed a few weeks later already. Despite the fact that a few dozen of them filed for insolvency, scaled back, idled or stopped production, the number of newcomers and their planned capacities is still exceeding the retired capacity.

The following chapter gives a short description of the 20 largest companies, in terms of actual production/shipments in 2011. More information about additional solar cell companies and details can be found in various market studies and in the country chapters of this report. The capacity, production or shipment data are from the annual reports or financial statements of the respective companies or the cited references.

3.2.1 Suntech Power Co. Ltd. (PRC)

Suntech Power Co. Ltd. (www.suntech-power.com) is located in Wuxi. It was founded in January 2001 by Dr. Zhengrong Shi and went public in December 2005. Suntech specialises in the design, development, manufacturing and sale of photovoltaic cells, modules and systems. For 2011, Suntech reported sales of 2,066 MW and shipments of 2,096 MW, taking the top rank amongst the solar cell manufacturers. The annual production capacity of Suntech Power was increased to 2.4 GW by the end of 2011, and the company plans not to expand its capacity in 2012.

3.2.2 First Solar LLC. (USA/Germany/Malaysia)

First Solar LLC (www.firstsolar.com) is one of the few companies world-wide to produce CdTe-thin-film modules. The company has currently three manufacturing sites in Perrysburg (USA), Frankfurt/Oder (Germany) and in Kulim (Malaysia), which had a combined capacity of 2.376 GW at the end of 2011. The second Frankfurt/Oder plant, doubling the capacity there to 528 MW, became operational in May 2011 and the expansion in Kulim increased the production capacity there to 1.584 GW at the end of 2011. In 2011, the company produced 1.98 GW. In the second quarter of 2012, the company reported production costs of 0.72 $/Wp (0.554 €/Wp), including restructuring, underutilisation and other non-manufacturing costs of 0.19 $/Wp (0.146 €/Wp).
In April 2021 the company announced a major restructuring to respond to the changing market conditions [Fir 2012]. The company announced to close the factory in Frankfurt/Oder, Germany, and idle four production lines in Kulim. In addition, it put the factory in Meza (AZ), USA on hold, and is selling the already built factory in the Dong Nam Industrial Park, Vietnam.

3.2.3 JA Solar Holding Co. Ltd. (PRC)

JingAo Solar Co. Ltd. (www.jasolar.com) was established in May 2005 by the Hebei Jinglong Industry and Commerce Group Co. Ltd., the Australia Solar Energy Development Pty. Ltd. and Australia PV Science and Engineering Company. Commercial operation started in April 2006 and the company went public on 7 February 2007. According to the company, the production capacity was 2.8 GW for cells, 1.2 GW for modules, and 1 GW for wafers at the end of 2011. For 2012, an increase in module capacity to 2 GW is foreseen. For 2011, sales of 1,695 MW are reported.

3.2.4 Yingli Green Energy Holding Company Ltd. (PRC)

Yingli Green Energy (www.yinglisolar.com) went public on 8 June 2007. The main operating subsidiary, Baoding Tianwei Yingli New Energy Resources Co. Ltd., is located in the Baoding National High-New Tech Industrial Development Zone. The company deals with the whole set, from solar wafers, cell manufacturing and module production. According to the company, production capacity reached 1.85 GW at the end of 2011. In August 2012, the company reached a total production capacity of 2.45 GW. The financial statement for 2011 reported shipments of 1.6GW.
In January 2009, Yingli acquired Cyber Power Group Limited, a development stage enterprise designed to produce polysilicon. Through its principle operating subsidiary, Fine Silicon, the company started trial production of solar-grade polysilicon in late 2009, and was still ramping up to full production capacity of 3,000 metric tons per year at the end of 2011. However, the financial results indicate that the company has written off its investment in Fine Silicon and according to other media reports the production is now closed down.
In January 2010, the Ministry of Science and Technology of China approved the application to establish a national-level key laboratory in the field of PV technology development, the State Key Laboratory of PV Technology at Yingli Green Energy's manufacturing base in Baoding.

3.2.5 Trina Solar Ltd, PRC (PRC)

Trina Solar (www.trinasolar.com) was founded in 1997 and went public in December 2006. The company has inte-

[16] **Solar cell production capacities mean:**
- In the case of wafer silicon based solar cells, only the cells
- In the case of thin-films, the complete integrated module
- Only those companies which actually produce the active circuit (solar cell) are counted
- Companies which purchase these circuits and make cells are not counted.

grated product lines, from ingots to wafers and modules.
In December 2005, a 30 MW monocrystalline silicon wafer product line went into operation. According to the company, the production capacity was 1.2 GW for ingots and wafers and 1.9 GW for cells and modules at the end of 2011. For 2011, it is planned to expand the capacities to 2.4 GW for cells and modules. For 2011, shipments of 1.51 GW were reported.
In January 2010, the company was selected by the Chinese Ministry of Science and Technology to establish a State Key Laboratory to develop PV technologies within the Changzhou Trina PV Industrial Park. The laboratory is established as a national platform for driving PV technologies in China. Its mandate includes research into PV-related materials, cell and module technologies and system-level performance. It will also serve as a platform to bring together technical capabilities from the company's strategic partners, including customers and key PV component suppliers, as well as universities and research institutions.

3.2.6 Motech Solar (Taiwan/PRC)
Motech Solar (www.motech.com.tw) is a wholly-owned subsidiary of Motech Industries Inc., located in the Tainan Science Industrial Park. The company started its mass production of polycrystalline solar cells at the end of 2000, with an annual production capacity of 3.5 MW. The production increased from 3.5 MW in 2001 to 1 GW in 2011.
In 2009, Motech started the construction of a factory in China, which reached its nameplate capacity of 500 MW in 2011. Total production capacity at the end of 2011 was given as 1.5 GW. For 2011, a combined production of 1.1 GW was reported.
In 2007, Motech Solar's Research and Development Department was upgraded to Research and Development Centre (R&D Centre), with the aim not only to improve the present production processes for wafer and cell production, but to develop next generation solar cell technologies. At the end of 2009, the company announced that it acquired the module manufacturing facilities of GE in Delaware, USA.

3.2.7 Canadian Solar Inc. (PRC)
Canadian Solar Inc. (CSI) (www.canadiansolar.com) was founded in Canada in 2001 and was listed on NASDAQ in November 2006. CSI has established six wholly-owned manufacturing subsidiaries in China, manufacturing ingot/wafer, solar cells and solar modules. According to the company, it had 228 MW of ingot and wafer capacity, 1.5 MW cell capacity and 2.1 GW module manufacturing capacity (1.9 GW in China, 218 MW in Ontario, Canada) in 2011.
For 2011, the company reported sales of 1.32 GW of modules, but no cell production figure was given, which must be lower, because the company states in its financial reports that it buys cells from other manufacturers. External reports gave the cell production at 1.05 GW [Pvn 2012].

3.2.8 SunPower Corporation (USA/Philippines/Malaysia)
SunPower (http://us.sunpowercorp.com) was founded in 1988, by Richard Swanson and Robert Lorenzini, to commercialise proprietary high-efficiency silicon solar cell technology. The company went public in November 2005. SunPower designs and manufactures high-performance silicon solar cells, based on an inter-digitated rear-contact design for commercial use. The initial products, introduced in 1992, were high-concentration solar cells with an efficiency of 26%. SunPower also manufactures a 22% efficient solar cell, called Pegasus, that is designed for non-concentrating applications.
SunPower conducts its main R&D activity in Sunnyvale, California, and has its cell manufacturing plants in the Philippines and Malaysia. In 2011, the company had two cell manufacturing plants outside of Manila, but decided to close down Fab. No 1 early 2012. Fab. No 1 had a nameplate capacity of 125 MW and Fab. No 2 has another nameplate capacity of 575 MW. Fab. No. 3, a joint venture with AU Optronics Corporation (AUO), with a planned capacity of 1.4 GW, is currently in a ramp-up phase with a production capacity of 600 MW at the end of 2011. The company has two solar module factories in the Philippines (600 MW) and since 2011, also Mexico (500 MW). In addition, modules are also assembled for SunPower by third-party contract manufacturers in China, Mexico, Poland, and California. Total cell production in 2011 was reported at 922 MW.

3.2.9 Gintech Energy Corporation (Taiwan)
Gintech (www.gintech.com.tw/) was established in August 2005 and went public in December 2006. Production at Factory Site A, Hsinchu Science Park, began in 2007 with an initial production capacity of 260MW and increased to 1,170 MW at the end of 2011. The company plans to expand capacity to 1.5GW in 2012. In 2011, the company had a production of 882 MW [Pvn 2012].

3.2.10 Sharp Corporation (Japan/Italy)
Sharp (www.sharp-world.com) started to develop solar cells in 1959 and commercial production got under way in 1963. Since its products were mounted on “Ume”, Japan's first commercial-use artificial satellite, in 1974, Sharp has been the only Japanese maker to produce silicon solar cells for use in space. Another milestone was achieved in 1980, with the release of electronic calculators, equipped with single-crystal solar cells.
In 2011, Sharp had a production capacity of 1,070 MWp/year, and shipments of 857 MW (637 MW c-si and 220-tf) were reported [Pvn 2012]. Sharp has two solar cell factories

in Japan, Katsuragi, Nara Prefecture, (550 MW c-Si and 160 MW a-Si their triple-junction thin-film solar cell) and Osaka (200 MW c-Si and 160 MW a-Si), and one together with Enel Green Power and STMicroelectronics in Catania, Italy (initial capacity 160 MW at the end of 2011), six module factories and the Toyama factory to recycle and produce silicon. Three of the module factories are outside Japan, one in Memphis, Tennessee, USA, with 100 MW capacity, one in Wrexham, UK, with 500 MW capacity and one in Nakornpathom, Thailand.

3.2.11 Hareon Solar Technology Co., Ltd.

Haeron Solar (www.hareonsolar.com) was established as the Jiangyin Hareon Technology Co., Ltd. in 2004 and changed its name to the Hareon Solar Technology Co., Ltd. in 2008. It has five manufacture facilities in both Jiangsu and Anhui province, including Jiangyin Hareon Power Co., Ltd., Altusvia Energy (Taicang) Co., Ltd., Hefei Hareon Solar Technology Co., Ltd., Jiangyin Xinhui Solar Energy Co., Ltd., and Schott Solar Hareon Co., Ltd. Solar cell production started in 2009, with an initial capacity of 70 MW. According to the company, the production capacity will be increased to over 2 GW for cells and 1 GW for modules in 2012. For 2011, a production of 855 MW is reported [Pvn 2012].

3.2.12 JinkoSolar Holding Co., Ltd.

Jinko Solar (www.jinkosolar.com) was founded by HK Paker Technology Ltd in 2006. Starting from up-stream business, the company expanded operations across the solar value chain, including recoverable silicon materials, silicon ingots and wafers, solar cells and modules in 2009. In May 2010, the company went public and is now listed at the New York Stock Exchange. According to the company, it had manufacturing capacities of 1.2 GW each for wafers, solar cells and solar modules at the end of 2011. For 2011, the company reported sales of about 812.6 MW (760.8 modules and 51.8 cells).

3.2.13 Neo Solar Power Corporation (Taiwan)

Neo Solar Power (www.neosolarpower.com) was founded in 2005 by PowerChip Semiconductor, Taiwan's largest DRAM company, and went public in October 2007. The company manufactures mono- and multicrystalline silicon solar cells. Production capacity of silicon solar cells at the end of 2011 was 1.3 GW. In 2011, the company had shipments of about 800 MW [Pvn 2012].

3.2.14 Q-Cells AG (Germany/Malaysia)

Q-Cells SE (www.qcells.de) was founded at the end of 1999 and is based in Thalheim, Sachsen-Anhalt, Germany. Solar cell production started in mid 2001, with a 12 MWp production line. The nominal capacity was 1.1 GW by the end of 2011, 500 MW in Germany and 600 MW in Malaysia. In the 2011 Annual Presentation, the company stated that production was 783 MW, including 66 MW of CIGS thin films from Solibro in 2011. Crystalline silicon solar cell production was 717 MW, 294 MW in Germany and 423 MW in Malaysia.

In the first half of the last decade, Q-Cells broadened and diversified its product portfolio by investing in various other companies, or forming joint ventures. Since the first half of 2009, Q-Cells has sold most of these holdings and now has one fully-owned solar cell manufacturing subsidiary, Solibro (CIGS).

In April 2012, the company filed for insolvency and was actively seeking a buyer of the operational business. On 29 August 2012, the creditors of Q-Cells approved the sale of the company to the South Korean conglomerate Hanwha.

3.2.15 Hanwha Solar One (PRC/South Korea)

Hanwha Solar One (www.hanwha-solarone.com) was established in 2004 as Solarfun Power Holdings, by the electricity meter manufacturer, Lingyang Electronics, the largest Chinese manufacturer of electric power meters.

In 2010, the Korean company, Hanwha Chemical, acquired 49.99% of the shares and a name change was performed in January 2011. The company produces silicon ingots, wafers, solar cells and solar modules. The first production line was completed at the end of 2004 and commercial production started in November 2005. The company went public in December 2006, and reported the completion of its production capacity expansion to 360 MW in the second quarter of 2008.

As of 30 March 202, the company reported the following capacities: 1.5 GW PV module production capacity, 1.3 GW of cell production capacity, 800 MW of ingot and wafer production capacity.

The 2011 annual production was reported with 367 MW ingots, 383 MW wafers, 687 MW solar cells and 939 MW modules.

3.2.16 Kyocera Corporation (Japan)

In 1975, Kyocera (http://global.kyocera.com/prdct/solar/) began with research on solar cells. The Shiga Yohkaichi Factory was established in 1980, and R&D and manufacturing of solar cells and products started with mass production of multicrystalline silicon solar cells in 1982. In 1993, Kyocera started as the first Japanese company to sell home PV generation systems.

Besides the solar cell manufacturing plants in Japan, Kyocera has module manufacturing plants in China (joint venture with the Tianjin Yiqing Group (10% share) in Tianjin since 2003), Tijuana, Mexico (since 2004) and in Kadan, Czech Republic (since 2005).

In 2011, Kyocera had a production of 660 MW, and is also marketing systems that both generate electricity through solar cells and exploit heat from the sun for other purposes, such as heating water. The Sakura Factory, Chiba Prefecture, is involved in everything from R&D and system planning to construction and servicing, and the Shiga Factory, Shiga Prefecture, is active in R&D, as well as the manufacturing of solar cells, modules, equipment parts, and devices, which exploit heat. Kyocera is planning to increase its current capacity of 800 MW in 2011 to 1 GW in 2012.

3.2.17 Renewable Energy Corporation AS (Norway/Singapore)

REC's (www.recgroup.com) vision is to become the most cost-efficient solar energy company in the world, with a presence throughout the whole value chain. REC is presently pursuing an aggressive strategy to this end. Through its various group companies, REC is already involved in all major aspects of the PV value chain. The company located in Høvik, Norway, has five business activities, ranging from silicon feedstock to solar system installations.
In 2011, the company decided to close down REC ScanCell, which was located in Narvik, and had a production capacity of 180 MW at the end of 2011. The next closure announced in March 2012, was the wafer factory in Glomfljord with a 300 MW capacity for multicrystalline wafers, whereas the 650 MW wafer plant at at Herøya continues operation. In 2012, production of solar cells and modules will only be done at REC Solar Singapore, which operates an integrated site for wafers, solar cells and modules production, with a capacity of 750 MW. In 2011, production was reported with 1,072 MW wafers, 699 MW modules and approximately 640 MW of cells.

3.2.18 TIANWEI Group (PRC)

Tianwei Group (www.btw.cn/en) is an affiliate of China South Industries Group Corporation (CSGC) and has various businesses, e.g. electricity transmission equipment, wind and photovoltaics (thin films and crystalline silicon). New Energy Holdings Co., Ltd. (www.twnesolar.com) is an integrated silicon solar cell company and has six subsidiaries, including the US silicon manufacturer Hoku Corporation. In 2007, the company invested in two 3,000 t polysilicon projects, namely Sichuan Xinguang Silicon Industry and Leshan Electric Power. However, it is not clear if the 6,000t capacity was reached, as some reports claim a shutdown of the plants in 2012. According to the company, it planned to increase the capacity of wafer, cell and modules to 1 GW each, by 2011, and 1.5GW, by 2012. For 2011, a cell production of 569 MW is reported [Pvn 2012].
Baoding TianWei Solar Films Co., Ltd. (www.btw-solarfilms.com) was set up in 2008. Phase I of the production was set-up with a capacity of 50 MW and the start of commercial operation was in the second half of 2009. The company plans to reach a capacity of 500 MW in 2015. For 2011, a production of 65 MW is reported [Pvn 2021].

3.2.19 LDK Solar Co. Ltd. (PRC)

LDK (www.ldksolar.com) was set up by the Liouxin Group, and is mainly known as a producer of polysilicon material. LDK Solar manufactures polysilicon, mono and multicrystalline ingots, wafers, cells, modules, systems, power projects and solutions. In 2010, the company set up a production line for solar cells, with a capacity of 120 MW, increased it to 1.7 GW in 2011 and plans to further increase it to 2.2GW in 2012. At the end of 2011, production capacities were as follows: 4.3 GW wafers, 1.7 GW solar cells, 1.5 GW solar modules. For 2011, the company reported a production of 590 MW solar cells, 840 MW solar modules and 1.5 GW of wafers.

3.2.20 Changzhou EGing Photovoltaic Technology Co. Ltd.

EGING PV (www.egingpv.com) was founded in 2003 and works along the complete photovoltaic industry value chain, from the production of monocrystalline furnaces, quartz crucibles, 5-8 inch monocrystalline silicon ingots, supporting equipment of squaring and wire sawing, monocrystalline silicon wafers, solar cells, and solar modules. According to the company, it has a production capacity of 1 GW across the complete value chain of ingot, wafer, cell and modules at the end of 2011. For 2011, sales of 584 MW were reported.

3.3 Polysilicon supply

The rapid growth of the PV industry since 2000 led to the situation where, between 2004 and early 2008, the demand for ***polysilicon*** outstripped the supply from the semiconductor industry. Prices for purified silicon started to rise sharply in 2007 and in 2008 prices for polysilicon peaked around 500 $/kg and consequently resulted in higher prices for PV modules. This extreme price hike triggered a massive capacity expansion, not only of established companies, but many new entrants as well. The top 10 silicon manufacturers produced about two-thirds of the 2011 total production.
The massive production expansions, as well as the difficult economic situation, led to a price decrease throughout 2009, reaching about 50–55 $/kg at the end of 2009, with a slight upwards tendency, throughout 2010 and early 2011, before prices dropped significantly and in August 2012 were trading in the 30 $/kg (23 €/kg) range for con-

tracted silicon and 20 $/kg (15 %/kg) on the spot market. For 2011, about 288,000 metric tons of solar grade silicon production, or double the 2010 volume were reported, sufficient for around 41 GW, under the assumption of an average materials need of 7 g/Wp [Gtm 2012]. China produced about 80,000 metric tons (sufficient to supply about 60 to 65 % of the domestic demand), and imported about 64,600 metric tons in 2011 [Cri 2012]. In 2011, China increased its production capacity to about 120,000 metric tons, but over half of the Chinese polysilicon manufacturers are small enterprises, and the annual production capacity is generally 1,000 - 3,000 metric tons.

In January 2011, the Chinese Ministry of Industry and Information Technology tightened the rules for polysilicon factories. New factories must be able to produce more than 3,000 metric tons of polysilicon a year and meet certain efficiency, environmental and financing standards. The total energy consumption must be less than 200 kWh/kg and China is aiming for large companies with at least 50,000 metric tons annual capacity by 2015. These two framing conditions, in addition to the enormous price pressure, are the reasons why a significant number of Chinese manufactures have closed down their production in the first half of 2012. This is also the reason why China already imported 48,000 metric tons of silicon during the first seven months of 2012, 35% more than during the same period last year [Etc 2012].

Projected silicon production capacities available for solar in 2012 vary between 328,000 metric tons [Ihs 2012] and 410,330 metric tons [Ikk 2012]. The possible solar cell production will, in addition, depend on the material used per Wp. The current world-wide average is about 6 g/Wp.

3.3.1 Silicon production processes

The high growth rates of the photovoltaic industry and the market dynamics forced the high-purity silicon companies to explore process improvements, mainly for two chemical vapour deposition (CVD) approaches – an established production approach known as the Siemens process, and a manufacturing scheme based on fluidised bed (FB) reactors. Improved versions of these two types of processes will very probably be the work-horses of the polysilicon production industry for the near future.

Siemens process – In the late 1950s, the Siemens reactor was developed and has been the dominant production route ever since. About 80% of total polysilicon manufactured world-wide was made with a Siemens-type process in 2009. The Siemens process involves deposition of silicon from a mixture of purified silane or trichlorosilane gas, with an excess of hydrogen onto high-purity polysilicon filaments. The silicon growth then occurs inside an insulated reaction chamber or "bell jar", which contains the gases. The filaments are assembled as electric circuits in series and are heated to the vapour deposition temperature by an external direct current. The silicon filaments are heated to very high temperatures between 1,100 – 1,175°C at which trichlorsilane, with the help of the hydrogen, decomposes to elemental silicon and deposits as a thin-layer film onto the filaments. Hydrogen Chloride (HCl) is formed as a by-product.

The most critical process parameter is temperature control. The temperature of the gas and filaments must be high enough for the silicon from the gas to deposit onto the solid surface of the filament, but well below the melting point of 1,414°C, that the filaments do not start to melt. Second, the deposition rate must be well controlled and not too fast, because otherwise the silicon will not deposit in a uniform, polycrystalline manner, making the material unsuitable for semiconductor and solar applications.

Fluidised bed process – A number of companies develop polysilicon production processes based on fluidised bed (FB) reactors. The motivation to use the FB approach is the potentially lower energy consumption and a continuous production, compared to the Siemens batch process. In this process, tetrahydrosilane or trichlorosilane and hydrogen gases are continuously introduced onto the bottom of the FB reactor at moderately elevated temperatures and pressures. At a continuous rate, high-purity silicon seeds are inserted from the top and are suspended by the upward flow of gases. At the operating temperatures of 750°C, the silane gas is reduced to elemental silicon and deposits on the surface of the silicon seeds. The growing seed crystals fall to the bottom of the reactor where they are continuously removed.

MEMC Electronic Materials, a silicon wafer manufacturer, has been producing granular silicon from silane feedstock, using a fluidised bed approach for over a decade. Several new facilities will also feature variations of the FB. Several major players in the polysilicon industry, including Wacker Chemie and Hemlock, are developing FB processes, while at the same time continuing to produce silicon using the Siemens process as well.

Upgraded metallurgical grade (UMG) silicon was seen as one option to produce cheaper solar grade silicon with 5- or 6-nines purity, but the support for this technology is waning in an environment where higher-purity methods are cost-competitive. A number of companies delayed or suspended their UMG-silicon operations as a result of low prices and lack of demand for UMG material for solar cells.

3.4 Polysilicon Manufacturers

World-wide more than 100 companies produce or started up polysilicon production. The following list gives a short description of the ten largest companies in terms of production in 2011. More information about additional polysilicon companies and details can be found in various market studies and the country chapters of this report.

3.4.1 OCI Company (South Korea)

OCI Company Ltd. (formerly DC Chemical) (www.oci.co.kr) is a global chemical company with a product portfolio spanning the fields of inorganic chemicals, petro and coal chemicals, fine chemicals, and renewable energy materials. In 2006, the company started its polysilicon business and successfully completed its 6,500 metric ton P1 plant in December 2007. The 10,500 metric ton P2 expansion was completed in July 2009 and P3 with another 10,000 metric tons brought the total capacity to 27,000 metric tons at the end of 2010. The debottlenecking of P3, took place in 2011, and increased the capacity to 42,000 tons at the end of the year. Further capacity expansions P4 (20,000 tons) and P5 (24,000 tons) have been put on hold due to the rapid price decline of polysilicon. Instead the company is pursuing a further debottlenecking of the existing plants to increase capacity by 10,000 metric tons by 2013.
For 2011, a production of 34,725 metric tons is reported [Gtm 2012].
OCI invested in downstream business and holds 89.1% of OCI Solar Power, which develops, owns and operates solar power plants in North America. On 23 July 2012, the company has signed a PPA with CSP Energy, Texas, for a 400 MW solar farm in San Antonio, TX.

3.4.2 Wacker Polysilicon (Germany)

Wacker Polysilicon AG (www.wacker.com), is one of the world's leading manufacturers of hyper-pure polysilicon for the semiconductor and photovoltaic industry, chlorosilanes and fumed silica. In 2011, Wacker increased its capacity to over 40,000 metric tons and reported sales of 32,000 metric tons. The 15,000 metric tons factory in Nünchritz (Saxony), Germany, started production in 2011. In 2010, the company decided to build a polysilicon plant in Tennessee with 15,000 tons capacity. The groundbreaking of the new 18,000 metric ton factory was in April 2011, and the construction should be finished at the end of 2013. In addition, the company is expanding the Burghausen capacity by 5,000 metric tons in 2012 and together with a further expansion of the Nünchritz factory by 5,000 metric tons, the company plans to have 70,000 metric tons of production capacity in 2014. Total polysilicon production is reported with 33,885 metric tons in 2011 [Gtm 2012].

3.4.3 Hemlock Semiconductor Corporation (USA)

Hemlock Semiconductor Corporation (www.hscpoly.com) is based in Hemlock, Michigan. The corporation is a joint venture of Dow Corning Corporation (63.25%) and two Japanese firms, Shin-Etsu Handotai Company, Ltd. (24.5%) and Mitsubishi Materials Corporation (12.25%). The company is the leading provider of polycrystalline silicon and other silicon-based products used in the semiconductor and solar industry.
In 2007, the company had an annual production capacity of 10,000 tons of polycrystalline silicon and production at the expanded Hemlock site (19,000 tons) started in June 2008. A further expansion at the Hemlock site, as well as a new factory in Clarksville, Tennessee, was started in 2009 and is still ongoing. Total production capacity was 46,000 metric tons in 2011 and the expansion to 56,000 metric tons should be finalised in 2012. For 2011 a production of 32,400 metric tons is reported [Gtm 2012].

3.4.4 GCL-Poly Energy Holdings Limited (PRC)

GCL-Poly (www.gcl-poly.com.hk) was founded in March 2006 and started the construction of their Xuzhou polysilicon plant (Jiangsu Zhongneng Polysilicon Technology Development Co. Ltd.) in July 2006. Phase I has a designated annual production capacity of 1,500 tons and the first shipments were made in October 2007. Full capacity was reached in March 2008. At the end of 2011, polysilicon production capacity had reached 65,000 metric tons and 8 GW of wafers. For 2011, the company reported a production of 29,414 metric tons of polysilicon with sales of 2,812 metric tons of polysilicon and 4.45 GW wafers.
In August 2008, a joint-venture, Taixing Zhongneng (Far East) Silicon Co. Ltd., started pilot production of trichlorsilane. Phase I will be 20,000 tons, with an expansion to 100,000 metric tons underway.
The company invested in the downstream business of solar. GCL Solar System Limited (SSL) is a wholly-owned subsidiary of GCL-Poly Energy Holdings Limited and provides solar system turnkey solutions for residential, governmental, commercial and solar farm projects, including design, equipment supply, installation and financial services. Another subsidiary is GCL Solar Power Co., Ltd., which is developing, operating and managing solar farms.

3.4 5 Renewable Energy Corporation AS (Norway)

REC's (www.recgroup.com) vision is to become the most cost-efficient solar energy company in the world, with a presence throughout the whole value chain. REC is presently pursuing an aggressive strategy to this end. Through its various group companies, REC is already involved in all major aspects of the PV value chain. The company located in Høvik, Norway has five business activities, ranging from

silicon feedstock to solar system installations.
In 2005, Renewable Energy Corporation AS ("REC") took over Komatsu's US subsidiary, Advanced Silicon Materials LLC ("ASiMI"), and announced the formation of its silicon division business area, "REC Silicon Division", comprising the operations of REC Advanced Silicon Materials LLC (ASiMI) and REC Solar Grade Silicon LLC (SGS). Production capacity at the end of 2011 was around 20,000 metric tons and according to the company, 16,672 metric tons electronic grade silicon was produced in 2011.

3.4.6 MEMC Electronic Materials Inc. (USA/Italy)

MEMC Electronic Materials Inc. (www.memc.com) has its headquarters in St. Peters, Missouri. It started operations in 1959 and the company's products are semiconductor-grade wafers, granular polysilicon, ultra-high purity silane, trichlorosilane (TCS), silicon tetraflouride (SiF_4), sodium aluminium tetraflouride (SAF). In February 2011, MEMC and Samsung announced a 50/50 joint venture to build a polysilicon plant in Korea with an initial capacity of 10,000 metric tons in 2013 [Mem 2011]. However, in December 2011 the company announced to idle its 6,000 metric ton Merano, Itlay factory in a major restructuring plan [Mem 2011b]. MEMC's production capacity at the end of 2011 was 15,000 metric tons [Sol 2012a]. Production was reported with 13,661 metric tons for 2011 [Gtm 2012].
MEMEC invested in the downstream business and acquired SunEdison, a developer of solar power projects and a solar energy provider, in 2009. During 2011 the company developed and acquired various projects. At the end of 2011, SunEdison had 255 MW under construction and 3 GW of projects in the pipeline.

3.4.7 LDK Solar Co. Ltd. (PRC)

LDK (www.ldksolar.com) was set up by the Liouxin Group, a company which manufactures personal protective equipment, power tools and elevators. With the formation of LDK Solar, the company is diversifying into solar energy products. LDK Solar went public in May 2007. In 2008, the company announced the completion of the construction and the start of polysilicon production in its 1,000 metric tons polysilicon plant. According to the company, the total capacity was 12,000 metric tons at the end of 2010, which will be increased to 25,000 tons in 2011. In 2011, polysilicon sales were reported at 10,455 metric tons.

3.4.8 Tokuyama Corporation (Japan)

Tokuyama (www.tokuyama.co.jp/) is a chemical company involved in the manufacturing of solar-grade silicon, the base material for solar cells. The company is one of the world's leading polysilicon manufacturers and produces roughly 16% of the global supply of electronics and solar grade silicon. According to the company, Tokuyama had an annual production capacity of 5,200 tons in 2008 and has expanded this to 9,200 tons in 2010. In February 2011, the company broke ground for a new 20,000 ton facility in Malaysia. The first phase with 6,200 metric tons should be finished in 2013 and the second phase with 13,800 metric tons in 2014. For 2011 a production of 8,800 tons is reported [Gtm 2012].
A verification plant for the vapour to liquid-deposition process (VLD method) of polycrystalline silicon for solar cells has been completed in December 2005. According to the company, steady progress has been made with the verification tests of this process, which allows a more effective manufacturing of polycrystalline silicon for solar cells.
Tokuyama has decided to form a joint venture with Mitsui Chemicals, a leading supplier of silane gas. The reason for this is the increased demand for silane gas, due to the rapid expansion of amorphous/microcrystalline thin-film solar cell manufacturing capacities.

3.4.9 Kumgang Korea Chemical Company (South Korea)

Kumgang Korea Chemical Company (KCC) (www.kccworld.co.kr/eng) was established by a merger of Kumgang and the Korea Chemical Co. in 2000. In February 2008, KCC announced its investment in the polysilicon industry and began to manufacture high-purity polysilicon with its own technology at the pilot plant of the Daejuk factory in July of the same year. In February 2010, KCC started to mass-produce polysilicon, with an annual capacity of 6,000 tons. For 2011 a production of 5,500 metric tons is reported [Gtm 2012].

3.4.10 Daqo New Energy Co., Ltd. (PRC)

Daqo New Energy (www.dqsolar.com) is a subsidiary company of the Daqo Group and was founded by Mega Stand International Limited in January 2008. The company started to build a high-purity polysilicon factory, with an annual output of 3,300 tons in the first phase in Wanzhou. The first polysilicon production line, with an annual output of 1,500 tons, started operation in July 2008. Production capacity in 2009 was 3,300 tons and reached more than 4,300 metric tons at the end of 2011. In the fourth quarter of 2012, expansion Phase 2 with 3,000 metric tons is scheduled to come on line and expansion Phase 3 with another 3,000 tons is scheduled for 2013. The company invested in the downstream business, ranging from wafers, cells, modules and projects. At the end of 2011, the company had a manufacturing capacity of 125 MW wafers and 100 MW modules. According to the company, it invested in solar cell production without giving a capacity. The company reported a polysilicon production of 4,524 metric tons in 2011.

4. Europe and the European Union

Over the last decade, primary energy production in the European Union has decreased by 14% mainly due to the decrease in oil (-46 %), coal and lignite (-37 %), gas (-22 %) and nuclear (-3 %) production, whereas primary energy production from renewable energy sources have increased by 80 % [Est 2011]. Energy dependence of the European Union on energy imports had increased to 54.8 % of energy imports in 2008 before it slightly decreased to about 53 % in 2010. However, without the significant growth of new renewable energy production in the European Union, the overall energy dependency would have increased to 57%. In 2010, EU27 spent about €355 billion on energy imports. The 4 % lowering of the import dependency led to a decrease of funds spent outside the Union of more than €14 billion.
One of the drivers behind the substantial growth of renewable energy production was that in March 2007, the European Council endorsed a binding target of a 20% share of renewable energies in the overall EU energy consumption by 2020, and a 10% binding minimum target to be achieved by all Member States for the share of biofuels in overall EU transport petrol and diesel consumption [CEU 2007].

In order to meet the new targets, the European Council called for an overall coherent framework for renewable energies, which resulted in the Directive on the "Promotion of the Use of Energy from Renewable Sources" [EC 2009]. Directive 2009/28/EC, which went into force on 25 June 2009, amends and subsequently repeals Directives 2001/77/EC and 2003/30/EC [EC 2001, EC 2003].

The main points of the new Directive are:

- Mandatory national overall targets and measures for the use of energy from renewable sources, as well as an indicative trajectory how to reach the targets;
- National Action Plans containing targets for transport, electricity and heating and cooling in 2020;
- Member States shall provide for either priority access or guaranteed access to the grid-system for electricity produced from renewable energy sources;
- Each Member State has to submit a report to the Commission on progress in the promotion and use of energy from renewable energy sources by 31 December 2011, and every two years thereafter. The sixth report to be delivered on 31 December 2021;
- Criteria and provisions to ensure sustainable production and use of bioenergy and to avoid conflicts between different uses of biomass.

This Directive exceeds the targets set within the White Paper "Energy for the Future: Renewable Sources of Energy" [EC 1997] and the Green Paper "Towards a European Strategy for the Security of Energy Supply" [EC 2000]. The goals were that renewable energies should provide 12% of the total and 21% of electric energy in the European Union by 2010, in order to meet the obligations of CO^2-reductions pledged in the Kyoto Protocol and to lower the dependence on energy imports.

The White Paper target for the cumulative photovoltaic systems capacity installed in the European Union by 2010 was 3,000 MW or a 100-fold increase of the capacity in 1995. It was assumed that electricity generation from these PV systems would then be in the order of 2.4 to 3.5 TWh, depending under which climatic conditions these systems are installed. The target was already achieved in 2006 and the cumulative installed capacity at the end of 2010 was over 29 GW, almost ten times the original target.

As depicted in Figure 8, the overall progress of the European Union towards the 2010 targets was very positive, with about 20% of the Union's total net electricity generation coming from renewable energy sources. However, it should be noted that this development fell short of the 21% needed, and after a 5% decrease of the electricity demand in 2009 compared to 2008, due to the economic crisis, electricity consumption in 2010 increased by 3.2% again. In addition, the development in the different Member States is quite diverse, as nine Member States have exceeded their targets, whereas some others are lagging behind.

The 2009 Directive indicates the overall percentage of renewable energies for the different Member States (Fig. 9), as well as the indicative trajectory (Fig. 10) how to reach it [EC 2009]. The decision on what kind of technologies to utilise in order to reach the national targets, is left to the Member States. By 30 June 2010, the Member States had to notify the Commission about their National Renewable Energy Action Plans (NRAPs). As stated in the Directive, the aim of these plans is *that all Member States, including those which so far have made very limited progress towards agreed EU objectives, will have to establish a clear plan as to how they intend to achieve their targets for renewable energy and for renewable energy in transport. They will have to explain how they intend to reform building codes and planning regimes to increase the use of renewable energy and to improve access conditions to the electricity grid. They will have to set out national sectoral targets, the measures and support schemes to be used to reach the targets, the specific measures for the promotion of the use of energy from biomass, the intended use of (statistical) transfers of renewable energy from other Member States and their assessment of the role different technologies will play in*

Fig. 8:
Electricity generation in TWh from renewable energies in the European Union [Est 2011a]

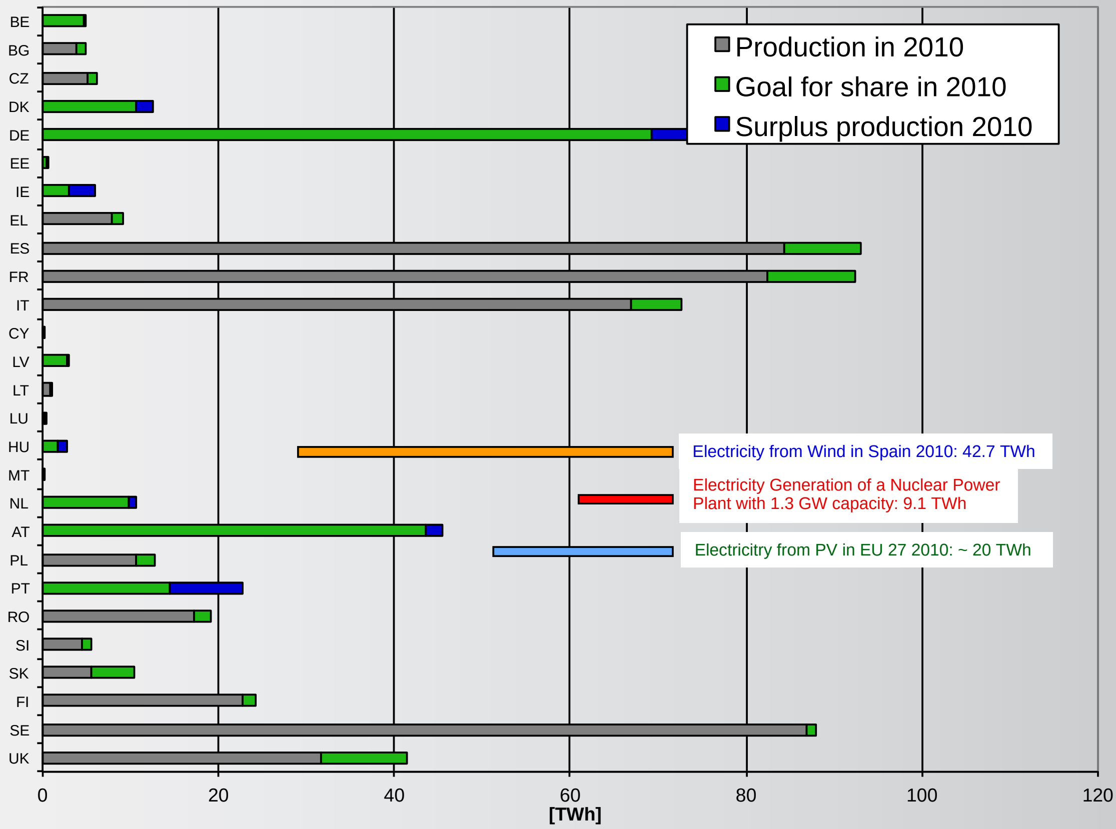


Fig. 9:
Share of renewable energies
in the European Union in 2020

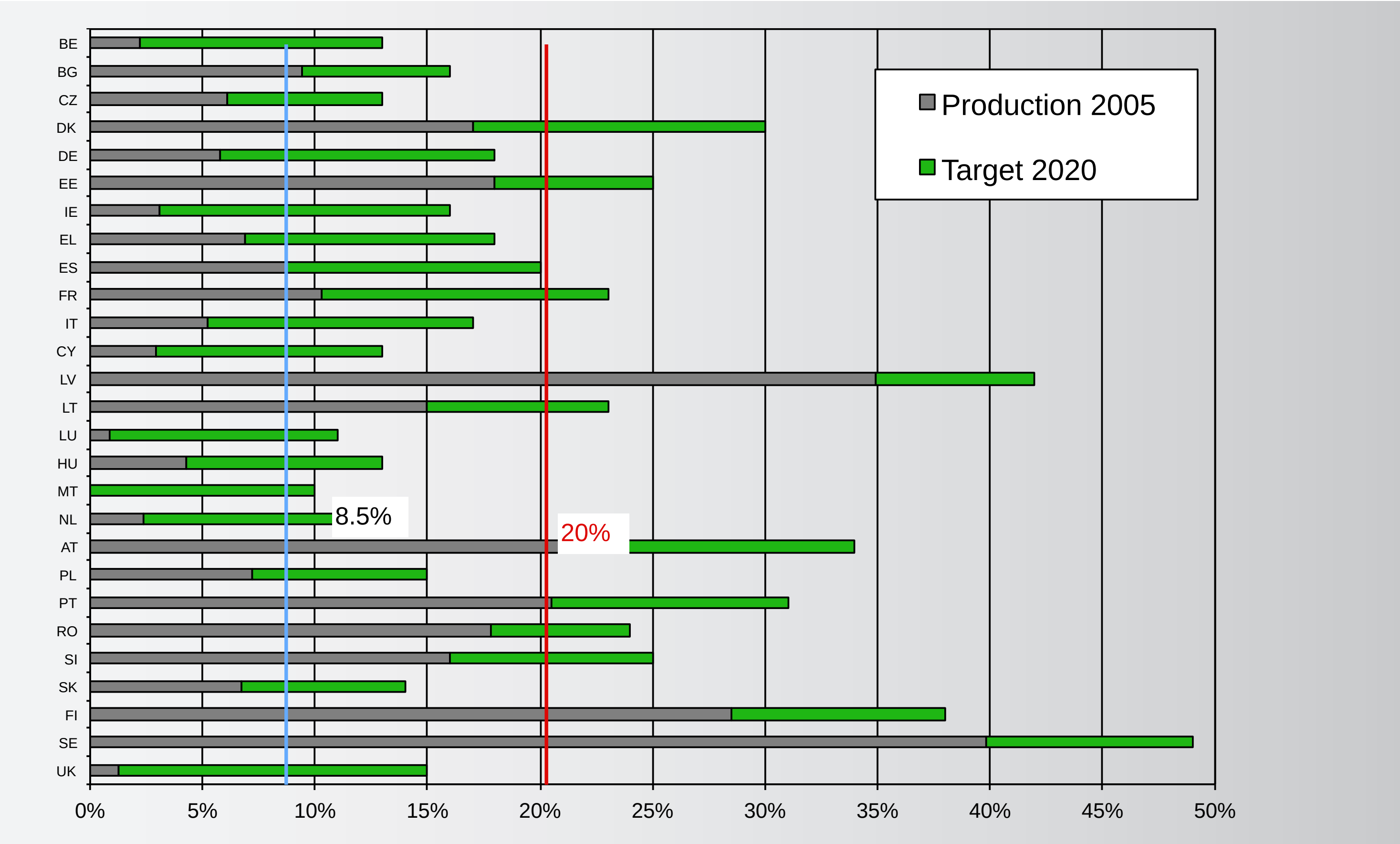
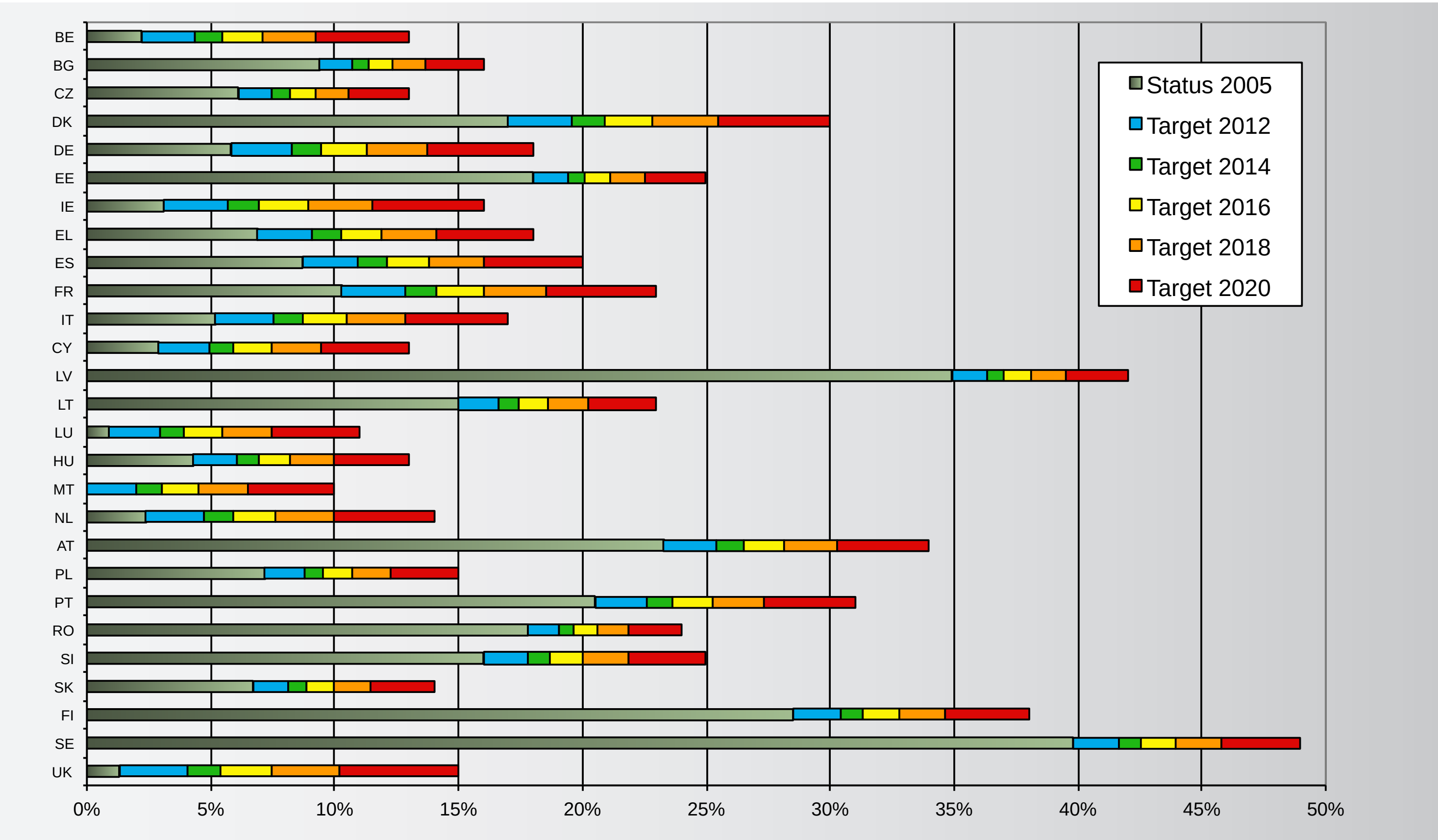


Fig. 10:
Trajectory to reach the share of renewable
energies in the European Union in 2020



and monitor biofuel sustainability criteria to ensure biofuels clearly contribute to our environmental objectives.

According to the NREAPs, renewable energies contributed 5,622 PJ or 11.6% of total gross final energy consumption in EU27 in 2010 [JRC 2011]. At the end of 2010 the European Union Member States estimated that about 640 TWh or 20 % of electricity came from renewable energy sources, out of which 310 TWh were non-hydro sources. To reach the 2020 targets renewable electricity should increase to 1,200 TWh in total and 850 TWh non-hydro sources, or 37% of Europe's electricity mix. Overall, this would correspond to total annual growth rates of 6.5% and 10.6% for non hydro sources, which for most technologies seem very moderate and non-ambitious targets.

In June 2012, the European Commission published a Communication entitled ***"Renewable Energy: a major player in the European Energy market"*** [EC 2012].
The Communication states:

The current renewable energy framework, of legally binding targets, national plans, administrative reform, simplification, better development and infrastructure planning appears to work well. According to Member State plans, the rate of growth of the sector will increase to 6.3% p.a. (2010 – 2012), up from the previous 4.5 % (2000 – 2010), boosting confidence in the future of the European renewable energy industry.

The communication further pointed out: As currently framed, the Renewable Energy Directive 2009/28/EC is designed to ensure the achievement of the 2020 renewable energy targets. It foresees a post-2020 roadmap in 2018. However, stakeholders have already been asking for clarity regarding policy developments after 2020. This is why the Commission believes it is important to start preparing now for the period beyond 2020.

4.1 Implementation of Photovoltaics in the European Union

The market conditions for photovoltaics differ substantially from country to country. This is due to different energy policies and public support programmes for renewable energies and especially photovoltaics, as well as the varying grades of liberalisation of domestic electricity markets. The legal framework for the overall increase of renewable energy sources was set with Directive 2009/28/EC, and in their National Renewable Energy Action Plans (NREAPs), 26 Member States have set specific photovoltaic solar energy targets, adding up to 84.5 GW in 2020 (Fig. 11). According to these NREAPs, 51.7 GW will come from Germany alone, which makes the balance even more uneven. Especially the sun-rich Mediterranean countries only pledged 24.6 GW (8.4 GW Spain, 8 GW Italy, 4.8 GW France, 2.2 GW Greece, 1.0 GW Portugal, and Cyprus and Malta together 220 MW) is far below (factor 2 to 6) the anticipated contribution of these sun-rich countries in order to reach 6 % of solar electricity by 2020, where a cumulative installed capacity of about 200 GW in Europe would be needed [Epi 2009].

The fact that most countries set rather moderate targets

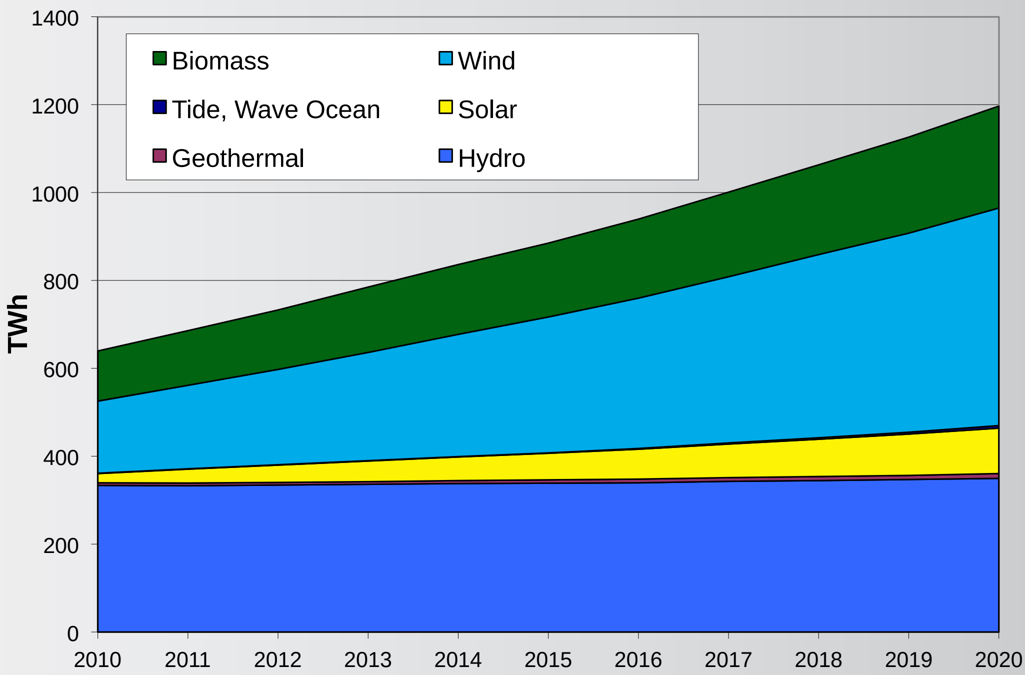


Fig. 11:
Planned European Union electricity production according to the National Renewable Energy Action Plans

for solar photovoltaic electricity systems resulted in an achievement of the 2020 targets by five countries already at the end of 2011. At the end of 2011 51.7 GW had been installed in the European Union and more than 52 GW in Europe as a whole. In August 2012, European PV capacity had surpassed 60 GW and more than 65 GW at the end of 2012 are very likely. This development indicates that the targets set in the NREAPs should be seen as the guaranteed minimum and not the overall goal.

The rapid growth of the European PV Market from 2 GW in 2007 to 18.5 GW in 2011, did not result in a similar growth of the European PV solar cell production, which was about 3.1 GW in 2010 and 2011. Compared to Asia, there is no single European production site with 1 GW or more and only two companies had more than 500 MW in 2011, with one to be closed down at the end of 2012. In an industry where economy of scale is crucial, production will go where the necessary funding for building the large scale factories is available.

Despite all research achievements, the European photovoltaic industries structure of a significant number of small to medium size companies, and the photovoltaic sector's lack of sufficient funding for fast growth large production facilities, has led to a decrease in global production market share which fell from 27% in 2006 to about 9% in 2011.

Within the last 12 months, about two dozen of European solar cell manufacturers have filed for bankruptcy, were sold to larger companies or closed down operations. If Europe as a research hub and production base for solar cells should remain, it needs two or three international champions competing successfully in the commodity market. Smaller companies should focus on higher value niche markets, which respond to more local needs and are not in the focus of the commodity product manufacturers.

However, looking only at the cell production does not grasp the whole picture of the whole PV value chain. Besides the manufacturing of solar cells, the whole upstream industry (e.g. materials, polysilicon production, equipment manufacturing), as well as the downstream industry (e.g. inverters, BOS components, system development, installations and integration into the existing or future electricity infrastructure) has to be looked at as well. It is worthwhile remembering that despite the fact that more than two-thirds of the solar cells which are installed in Germany are not produced there, about 60% of the added value remains within the German economy.

In some European countries, like Germany or Italy, the installed PV capacity will exceed 30% and 20% of the installed thermal power plant capacities respectively at the end of 2012. Already on 25 May 2012, more than 22 GW of solar power were on the German grid, covering more than 30% of the total electricity demand at noon. To effectively handle these high shares of renewable electricity, new technical and regulatory solutions have to be implemented in order not to run into the problem of curtailing large parts of this electricity. The integration into existing electricity infrastructure is a research and business field, where Europe can make its mark if it reacts now. A positive example is the Italian National Grid Operator TERNA which outlined in its new strategic plan 2012 – 2016 a shift of investments from its traditional transmission business into new business opportunities covering renewables, storage systems (batteries and pumped storage) and energy efficiency [Ter 2012].

The dominating support measures for photovoltaics in the European Union Member States and Switzerland are feed-in tariffs. The rapid decrease of photovoltaic system prices led to a number of sometimes drastic revisions in the feed-in schemes. The existing support schemes are listed in Table 1.

The majority of the 34 States listed above have introduced feed-in tariffs. However, the efficiency of this measure to exploit these countries' PV-potential varies considerably, in function of the details in each national regulation.

With a few exceptions, the New Member States and Candidate Countries still have much lower installation figures, despite good to very good solar resources, in some States with up to 1,600 kWh/kWp (Cyprus, Malta, Romania, Bulgaria, and South-East Hungary). Even in the Baltic States, yearly average values of more than 800 kWh per year are possible for a 1 kWp system, which is comparable to Northern Germany [Šúr 2004].

Retail prices for solar Photovoltaic electricity systems depended on the price for hardware components (i.e. solar modules, inverters, mounting systems, cables etc), labour costs for the installation, financing costs, permitting costs, insurances and profits. In 2012 the PV module market is global and more or less the same prices can be found all over. Inverter costs may vary depending on the regulatory requirements in the different countries. However, the biggest difference can still be found in the so-called "soft cost", which mainly consist of financing and permitting costs, as well as installer/system integrator profits.

Table 1:
Support mechanisms for photovoltaics in the European Union, Accession Country, Candidate Countries, Switzerland and Ukraine

Austria	The Ökostromverordnung 2012 (eco electricity degree) set the following new tariffs for 2012 (only for PV systems covered by the Ökostromgesetz (Eco Electricty Law). Systems on buildings or noise barriers: ■ System size between 5 and 20 kWp: 0.275 €/kWh ■ System size > 20 kWp: 0.23 €/kWh Free-standing systems: ■ System size between 5 and 20 kWp: 0.25 €/kWh ■ System size > 20 kWp: 0.19 €/kWh The tariff is paid for 13 years, and the annual budget for new installations is € 0.5 million. For systems smaller than 5 kWp, the Climate & Energy Fund, which has in 2012 a budget of € 255 million, offered an investment subsidy to private persons. For 2012, the investment subsidies are as follows: ■ Rooftop and free-standing systems: 800 €/kWp ■ Building integrated systems: 950 €/kWp Some of the Federal States have additional investment support schemes.
Belgium	Green Certificates (with guaranteed minimum price): ■ **Brussels:** from 1 August 2012: 4 GC per MWh for 10 years ■ **Wallonia:** (10 years) For systems smaller 5 kWp 1 December 2011 to 31 March 2012: 7 GC per MWh For additional system capacity between 5 and 10 kWp 1 December 2011 to 31 March 2012: 5 GC per MWh From 1 April 202 on, a system to start with 10 GC in the first year and reduce it to 2 over 10 years was introduced. For systems smaller than 10 kWp this resulted in a total of 60 GC over ten years. A further reduction to start with 8 CG in the first year and decrease to 2 started 1 September 2012 resulting in a total of 50 GC for those installations. In addition, the value of the CG was lowered to 54 €/MWh for the period 1 July to 31 December 2012. ■ **Flanders** Systems larger than 250 kWp from 1 January 2012: 0.09 €/kWh for 20 years from 1 August 2012: 0.09 €/kWh for 10 years Systems smaller than 250 kWp 1 January to 31 March: 0.25 €/kWh for 20 years 1 April to 30 June: 0.23 €/kWh for 20 years

from 1 July: 0.21 €/kWh for 20 years
from 1 August 2012: 0.09 €/kWh for 20 years.
For all systems from 1 January 2013: 0.092 €/kWh

Net meeting possible for systems smaller than 10 kWp in Brussels

Bulgaria

In 2011 the duration of FIT payments was changed to 20 years for PV systems.
The tariffs for 2012 were set by the regulator on 31 March 2011 until 31 June 2012.
Changes to the tariffs were done in June and August 2012 to reflect the changes in PV system prices.
The State Energy and Water Regulation Commission (SEWRC) set the tariffs as follows:

From 1 July 2011 to 30 June 2012
– roof & façade mounted systems
- 0.605 BGN/kWh (0.310 €/kWh[17]) for systems up to 30 kW
- 0.597 BGN/kWh (0.306 €/kWh) for systems between 30 kW and 200 kW
- 0.583 BGN/kWh (0.299 €/kWh) for systems between 0.2 and 1 MW

– ground mounted systems
- 0.576 BGN/kWh (0.295 €/kWh) for systems up to 30 kW
- 0.567 BGN/kWh (0.291 €/kWh) for systems between 30 kW and 200 kW
- 0.486 BGN/kWh (0.249 €/kWh) for systems above 200 kW

From 1 July to 31 August 2012
– roof & façade mounted systems
- 0.401 BGN/kWh (0.206 €/kWh) for systems up to 30 kW
- 0.396 BGN/kWh (0.203 €/kWh) for systems between 30 kW and 200 kW
- 0.316 BGN/kWh (0.162 €/kWh) for systems between 0.2 and 1 MW

– ground mounted systems
- 0.269 BGN/kWh (0.138 €/kWh) for systems up to 30 kW
- 0.261 BGN/kWh (0.134 €/kWh) for systems between 30 kW and 200 kW
- 0.237 BGN/kWh (0.122 €/kWh) for systems between 0.2 and 10 MW
- 0.236 BGN/kWh (0.121 €/kWh) for systems above 10 MW

From 1 September 2012
– roof & façade mounted systems
- 0.381 BGN/kWh (0.195 €/kWh) for systems up to 5 kW
- 0.290 BGN/kWh (0.149 €/kWh) for systems between 5 and 30 kW
- 0.227 BGN/kWh (0.116 €/kWh) for systems between 30 kW and 200 kW
- 0.206 BGN/kWh (0.106 €/kWh) for systems between 0.2 and 1 MW

– ground mounted systems
- 0.193 BGN/kWh (0.099 €/kWh) for systems up to 30 kW
- 0.188 BGN/kWh (0.096 €/kWh) for systems between 30 kW and 200 kW
- 0.171 BGN/kWh (0.088 €/kWh) for systems between 0.2 and 10 MW
- 0.170 BGN/kWh (0.087 €/kWh) for systems above 10 MW

[17] Exchange rate: 1 € = 1.95 BGN

In addition, SEWRC has published temporary prices – in accordance with the Energy Act amendments adopted by the Bulgarian Parliament in July 2012 [GoB 2012a] for access to the transmission and distribution grid on 14 September 2012. These temporary access fees apply to all PV systems connected since 1 April 2010 and decrease the revenues of the system operators between 1 and 39% depending when the system went into operation [Sew 2012].

Croatia

In May 2012 the government of the Republic of Croatia has introduced a new Tariff system for electrical energy from renewable energy sources and cogeneration [GoH 2012].

For solar systems the tariffs were set as:

Roof-top systems: 10 MW cap
- System size < 10 kW: 2.63 HRK/kWh (0.350 €/kWh[18])
- System size 10 to 30 kW: 2.23 HRK/kWh (0.298 €/kWh)
- System size 30 to 300 kW: 1.650 HRK/kWh (0.220 €/kWh)

Ground mounted systems: 5 MW cap
- System size < 10 kW: 2.00 HRK/kWh (0.267 €/kWh)
- System size 10 kW to 10 MW: 1.10 HRK/kWh (0.146 €/kWh)

[18] Exchange rate: 1 € = 7.5 HRK

Cyprus

At the moment, there are three PV system categories with different feed-in tariff levels and application procedures in Cyprus.

- Residential PV systems up to 7 kW: 0.28 €/kWh for 15 years
  (Cap: 5MW)
- Commercial PV systems up to 150kW: 0.25 €/kWh for 20 years
  This category also serves those applications which could not be approved under the previous support schemes (24.5 MW).
  (Cap: 26.45MW)

- Commercial PV system with capacities between 150 kW – 10 MW:
  The actual tariff will be determined through a bidding process which closed in July 2012. Maximum acceptable price will be 0.21 €/kWh for 20 years
  (Cap: 50 MW)

Czech Republic

Feed-in tariff for 20 years. Annual prices are set by the Energy Regulator. For 2012 the tariffs were set in November 2011 with Decision No. 7/2011. Producers of electricity can choose from two support schemes:

- Fixed tariff:
  Systems commissioned after 01/01/12:
  ≤ 30 kW: 6.16 CZK/kWh (0.247 €/kWh)[19]

- Market price + Green Bonus; Green Bonus
  Systems commissioned after 01/01/12:
  ≤ 30 kW: 5.08 CZK/kWh (0.203 €/kWh)

From 1 January 2011 on, the revenues of PV systems put into operation between 1 Jan 2009 and 31 Dec 2010 are subject to a tax of 26% and the green bonus is subject to 28% tax. Exception: Roof-top and facade-integrated systems with a capacity of up to 30 kW.

[19] Exchange rate: 1 € = 24.98 CZK

Denmark

Net-metering scheme was introduced in 2010. Due to the high household electricity retail price of over 0.28 €/kWh, including levies and taxes, net metering provides a sustainable incentive to support the installation of PV systems.

Estonia

No specific PV programme, but Renewable Portfolio Standard and tax relief. Feed-in tariff for 12 years for electricity produced out of RES, except wind, is:

- 0.85 EEK/kWh (0.054 €/kWh)[20] for systems with start of operation 2010 and after.

[20] Exchange rate: 1 € = 15.64 EEK

Finland

No PV programme, but investment subsidy up to 40% and tax/production subsidy for electricity from renewable energy sources (6.9 €/MWh).

FYR Macedonia

In 2010 FYR Macedonia set an indicative RES target of 21% for 2020. In 2011 FYRM adopted an Energy Law in 2011 and introduced preferential electricity tariffs (feed-in tariffs) for the production of RES-Electricity [GoM 2011, 2011a].

The tariffs for PV systems are paid for 15 years and were set as:

- P < 50 kW: 0.30 €/kWh
- 50 kW < P < 1 MW: 0.26 €/kWh

France

Feed-in tariff for 20 years
In 2012 the tariffs changed every quarter. On 1 January 2012 a 10% decrease took place, a second and third decrease depending on the type of installation took place on 1 April ranging between 2.6 and 9.5% and on 1 July ranging between 2.5 and 10%. For the third trimester, 1 July to 30 September 2012 the tariffs were set as follows:

Residential:		
BIPV:	≤ 9kWp	0.354 €/kWh
	9 < P ≤ 36 kWp	0.309 €/kWh
Simplified BIPV:	≤ 36 kWp	0.184 €/kWh
	36 < P < 100 kWp	0.175 €/kWh
Health Care Institutions:		
BIPV:	≤ 36 kWp	0.246 €/kWh
Simplified BIPV:	≤ 36 kWp	0.184 €/kWh
	36 < P < 100 kWp	0.175 €/kWh
Other Buildings:		
BIPV:	≤ 9kWp	0.214 €/kWh
Simplified BIPV:	≤ 36kWp	0.184 €/kWh
	36 < P < 100 kWp	0.175 €/kWh
All Other Installations:	≤ 12 MWp	0.105 €/kWh

Germany

Feed-in tariff for 20 years
The last revision of the tariffs was published in August 2012, but regulates the tariffs with monthly degressions from 1 April 2012 on:
Start of Operation from 1 April 2012
Roof-top systems:
- System size < 10 kW: 0.195 €/kWh
- System size 10 to 40 kW: 0.185 €/kWh and max 90% output
- System size 40 kW to 1 MW: 0.165 €/kWh and max 90% output
- System size 1 to 10 MW: 0.135 €/kWh

Free-field systems up to 10 MW 0.135 €/kWh
Start of Operation from 1 May 2012
Roof-top systems:
- System size < 10 kW: 0.193 €/kWh
- System size 10 to 40 kW: 0.183 €/kWh and max 90% output
- System size 40 kW to 1 MW: 0.163 €/kWh and max 90% output
- System size 1 to 10 MW: 0.134 €/kWh

Free-field systems up to 10 MW 0.134 €/kWh
Start of Operation from 1 June 2012
Roof-top systems:
- System size < 10 kW: 0.191 €/kWh
- System size 10 to 40 kW: 0.181 €/kWh and max 90% output
- System size 40 kW to 1 MW: 0.162 €/kWh and max 90% output
- System size 1 to 10 MW: 0.132 €/kWh

Free-field systems up to 10 MW 0.132 €/kWh

Start of Operation from 1 July 2012
Roof-top systems:

- System size < 10 kW: 0.189 €/kWh
- System size 10 to 40 kW: 0.180 €/kWh and max 90 % output
- System size 40 kW to 1 MW: 0.160 €/kWh and max 90 % output
- System size 1 to 10 MW: 0.131 €/kWh

Free-field systems up to 10 MW 0.131 €/kWh
Start of Operation from 1 August 2012
Roof-top systems:

- System size < 10 kW: 0.187 €/kWh
- System size 10 to 40 kW: 0.178 €/kWh and max 90 % output
- System size 40 kW to 1 MW: 0.159 €/kWh and max 90 % output
- System size 1 to 10 MW: 0.130 €/kWh

Free-field systems up to 10 MW 0.130 €/kWh
Start of Operation from 1 September 2012
Roof-top systems:

- System size < 10 kW: 0.185 €/kWh
- System size 10 to 40 kW: 0.176 €/kWh and max 90 % output
- System size 40 kW to 1 MW: 0.157 €/kWh and max 90 % output
- System size 1 to 10 MW: 0.128 €/kWh

Free-field systems up to 10 MW 0.128 €/kWh
Start of Operation from 1 October 2012
Roof-top systems:

- System size < 10 kW: 0.184 €/kWh
- System size 10 to 40 kW: 0.174 €/kWh and max 90 % output
- System size 40 kW to 1 MW: 0.155 €/kWh and max 90 % output
- System size 1 to 10 MW: 0.127 €/kWh

Free-field systems up to 10 MW 0.127 €/kWh
Start of Operation from 1 November 2012

The degression rate will be determined by the regulatory authority depending on the actual installed capacity between July and September 2012.

The revision set an annual corridor of 2.5 to 3.5 GW of new installations. If this corridor is surpassed or underutilised, the monthly degression from 1 December 2012 on will increase or decrease in accordance to the actual installation rate. The feed-in tariff scheme will automatically end in the following month once a total capacity of 52 GW is reached.

Greece

After an adoption on 1 February 2012, the tariffs were again changed to reflect the market developments and went into effect on 1 August 2012.

Start of Operation from 1 August 2012
Roof-top systems < 10 kW: 0.250 €/kWh for 25 years
- System between 10 and 100 kW: 0.225 €/kWh for 20 years
- System size more than 100 kW: 0.180 €/kWh for 20 years

Start of Operation from 1 February 2013
Roof-top systems < 10 kW: 0.239 €/kWh for 25 years
- System between 10 and 100 kW: 0.215 €/kWh for 20 years
- System size more than 100 kW: 0.172 €/kWh for 20 years

Start of Operation from 1 August 2013
Roof-top systems < 10 kW: 0.228 €/kWh for 25 years
- System between 10 and 100 kW: 0.205 €/kWh for 20 years
- System size more than 100 kW: 0.164 €/kWh for 20 years

Start of Operation from 1 February 2014
Roof-top systems < 10 kW: 0.218€/kWh for 25 years
- System between 10 and 100 kW: 0.196 €/kWh for 20 years
- System size more than 100 kW: 0.157 €/kWh for 20 years

Start of Operation from 1 August 2014
Roof-top systems < 10 kW: 0.208 €/kWh for 25 years
- System between 10 and 100 kW: 0.187 €/kWh for 20 years
- System size more than 100 kW: 0.150 €/kWh for 20 years

In addition there will be a partly regulated inflation adjustment.

Hungary

Support for RES is regulated through the Electricity Act, which entered into force on 1 January 2003.
From January 2011 onwards the feed-in tariff (no difference during the day) for PV was approved after 1 January 2008: 29.84 HUF/kWh (0,103 €/kWh[21])

For Systems of more than 50 MW (date of approval irrelevant):
- peak time: 20.74 HUF/kWh (0,072 €/kWh)
- mid-peak time: 13.27 HUF/kWh (0,046 €/kWh)
- off-peak time: 13.27 HUF/kWh (0,046 €/kWh)

[21] Exchange rate: 1 € = 290 HUF

Italy

Feed-in tariff guaranteed for 20 years. 2% decrease for new systems each year. The 5th *Conto Energia* was passed in July 2012 [Gaz 2012]. The decree applies to plants connected in the second half of 2012 and before 31 December 2014.

The tariffs are being reduced on a half-yearly base:

System size [kWp]	Systems on buildings		other installations	
	all inclusive [€/kWh]	with self consumption [€/kWh]	all inclusive [€/kWh]	with self consumption [€/kWh]
2nd H 2012:				
1 ≤ P ≤ 3	0.237	0.155	0.229	0.147
3 < P ≤ 20	0.222	0.140	0.214	0.132
20< P < 200	0.199	0.117	0.191	0.109
200 < P < 1 MW	0.161	0.079	0.153	0.071
1 MW < P < 5 MW	0.144	0.062	0.137	0.055
P > 5 MW	0.135	0.053	0.128	0.046
1st H 2013:				
1 ≤ P ≤ 3	0.207	0.125	0.200	0.118
3 < P ≤ 20	0.195	0.113	0.188	0.106
20< P < 200	0.178	0.096	0.172	0.090
200 < P < 1 MW	0.148	0.066	0.141	0.059
1 MW < P < 5 MW	0.135	0.053	0.129	0.047
P > 5 MW	0.127	0.045	0.121	0.039
2nd H 2013:				
1 ≤ P ≤ 3	0.178	0.096	0.173	0.091
3 < P ≤ 20	0.169	0.087	0.163	0.081
20< P < 200	0.160	0.078	0.154	0.072
200 < P < 1 MW	0.135	0.053	0.129	0.047
1 MW < P < 5 MW	0.125	0.043	0.120	0.038
P > 5 MW	0.118	0.036	0.113	0.031
1st H 2014:				
1 ≤ P ≤ 3	0.164	0.082	0.159	0.077
3 < P ≤ 20	0.156	0.074	0.151	0.069
20< P < 200	0.148	0.066	0.143	0.061
200 < P < 1 MW	0.127	0.045	0.122	0.040
1 MW < P < 5 MW	0.119	0.037	0.115	0.033
P > 5 MW	0.113	0.031	0.108	0.026
2nd H 2014:				
1 ≤ P ≤ 3	0.152	0.070	0.147	0.065
3 < P ≤ 20	0.145	0.063	0.141	0.059
20< P < 200	0.138	0.056	0.134	0.052
200 < P < 1 MW	0.120	0.038	0.116	0.034
1 MW < P < 5 MW	0.113	0.031	0.110	0.028
P > 5 MW	0.108	0.026	0.104	0.022

Italy (part 2)

Tariffs for integrated innovative systems:

2nd H 2012:

System size [kWp]	all inclusive [€/kWh]	with self consumption [€/kWh]
1 ≤ P ≤ 20	0.225	0.173
20 < P ≤ 200	0.232	0.150
P > 200	0.216	0.134
1st H 2012:		
1 ≤ P ≤ 20	0.223	0.141
20 < P ≤ 200	0.207	0.125
P > 200	0.195	0.113
2nd H 2013:		
1 ≤ P ≤ 20	0.189	0.107
20 < P ≤ 200	0.180	0.098
P > 200	0.171	0.089
1st H 2014:		
1 ≤ P ≤ 20	0.173	0.091
20 < P ≤ 200	0.165	0.083
P > 200	0.158	0.076
2nd H 2014:		
1 ≤ P ≤ 20	0.159	0.077
20 < P ≤ 200	0.153	0.071
P > 200	0.146	0.064

Latvia

Feed-in tariff for RES, but not PV specific:
Licensed before 1. 6.2001: double the average sales price (~ 0.101 €/kWh) for eight years, then reduction to normal sales price.
Licensed after 1.6.2001: Regulator sets the price.
The feed-in system has been amended through Regulation No. 503 on Electricity Production from RES (in force since August 2007), but without PV provisions.
A national investment programme for RES has been running since 2002.

Lithuania

Feed-in tariffs are set by the National Control Commission for Prices and Energy (NCC). For systems larger than 30 kW the price will be determined by auctions. Maximum price for installations in 2012 (12 years):

Building integrated systems

P < 30 kW	1.80 LTL/kWh (0.522 €/kWh[21])
30 < P < 100 kWp	1.66 LTL/kWh (0.481 €/kWh)
P > 100 kWp	1.28 LTL/kWh (0.371 €/kWh)

All other systems

P < 30 kW	1.44 LTL/kWh (0.417 €/kWh)
30 < P < 100 kWp	1.33 LTL/kWh (0.386 €/kWh)
P > 100 kWp	1.04 LTL/kWh (0.301 €/kWh)

[21] Exchange Rate: 1 € = 3.45 LTL

Luxembourg

A support scheme was set with a "Règlement Grand Ducal" in September 2005. The Règlement had a cap of 3 MW by 2007. The feed-in tariffs have been amended in February 2008 and a new cap of 5 MW has been set. Tariffs are guaranteed over 15 years with simpler administrative procedures. They are differentiated according to technology and capacity. Some tariffs are degressive. In the case of photovoltaics only roof-top systems are eligible and the tariff for 2012 is set as follows:

- System size ≤ 30 kW:0.369 €/kWh
- System size 30 < P ≤ 1 MW: 0.325 €/kWh

Malta

Feed-in Tariff:

Malta:	P ≤ 3	0.25 €/kWh	8 years
	3 < P ≤ 100	0.20 €/kWh	8 years
	100< P	case by case	8 years
Gozo:	P ≤ 3	0.28 €/kWh	8 years
	3 < P £ 100	0.20 €/kWh	8 years
	100< P	case by case	8 years

Montenegro

In September 2011 the Government of Montenegro introduced feed-in tariffs for renewable energy sources [GoM 2011b].
The tariffs for solar were set as:

- For PV systems on buildings and structures: 0.15 €/kWh
- For PV plants on solid waste landfills: 0.09 €/kWh

Netherlands

The SDE *('Stimuleringsregeling duurzame energieproductie')* system from 2007 was changed in 2011 to SDE+ where the individual technologies no longer have their own brackets, but compete against each other. The allocation of funds is made in five calls with different, increasing incentive levels on a first-come first-served basis.
PV systems with a capacity below 15 kW are eligible for a net metering scheme with an annual limit of 5,000 kWh.

Poland

No specific PV programme. In January 2007, changes in the Energy Law Act were made, resulting in the requirement of an energy generation licence, regardless of the power installed (previously required only > 50 MW).
An excise tax exemption on RES-E was introduced in 2002. It amounts to 0.02 PLN/kWh (0.483 €cent/kWh)[23].
Green Certificates are available for all RE technologies. They have a value of about 0.25 PLN/kWh (0.060€/kWh)
In July 2012 a draft law on the support of renewable energy sources was published, which would implement a feed-in tariff in the future.

[23] Exchange Rate: 1 € = 4.137 PLN

Portugal

In October 2010 a feed-in tariff for small systems [Dia 2010] and in March 2011 for medium sized systems [Dia 2011], was introduced.

Small systems (up to 5 kW and 11 kW for condominiums):
- 0.326 €/kWh for the first eight years and 0.185 €/kWh for the next seven years.

The annual electricity amount is limited to 2.4 MWh/a per kW installed and an annual cap of 25 MW for new installations is in place. An annual reduction of 0.02 €/kWh for new systems is foreseen.

Medium-sized systems (up to 250 kW):
- 0.215 €/kWh for 15 years and the tariff for new systems decreases 7 % each year.

The annual electricity amount is limited to 2.6 MWh/a per kW installed and an annual cap of 50 MW for new installations is in place.

Tender system for large systems. However, on 6 February 2012, the Portuguese Decree Law 25/2012 has suspended indefinitely, and with immediate effect, the allocation of new power for renewable electricity production.

Romania

No specific programme for PV. For the promotion of the production of electricity from Renewable Energy Sources, a system of Tradable Green Certificates is in place. For PV systems 1 MWh produced receives 6 GC until 2017. However, there is a limitation on the IRR and when this turns out to be too high (>11.9 % for PV) then new entrants (after 01/01/2013) will get less GCs.
For the period 2005-2012, the annual maximum and minimum value for Green Certificates trading is 27 € per certificate, respectively 55 € per certificate, calculated at the exchange rate established by the Romanian National Bank, for the last working day of December of the previous year.
The penalty level is 110 €/MWh.

Serbia

On 20 November 2009 the Serbian Government adopted the Incentives Decree for the "Production of Electricity from Renewable Energy Sources and the Combined Production of Electricity and Heat", which came into force on 1 January 2010 and shall remain effective until 31 December 2012 [GoS 2009].
PV systems up to 5 MW are eligible for a tariff of 0.23 €/kWh for 12 years.

Slovakia

From 1 February 2011, on only solar rooftop facilities or solar facilities on the exterior wall of buildings with capacity not exceeding 100 kW are eligible for the feed-in tariff. Feed-in tariff guaranteed for 12 years is set by the Regulator each year.
2012 feed-in tariff: 0.195 €/kWh
In addition, PV, like all other RES, qualifies for investment subsidies under the framework of the EU Structural Funds.

Slovenia

A revised feed-in tariff scheme went into force in 2009. The main changes were that the guaranteed period changed from 10 to 15 years and that the tariffs were differentiated according to system sizes and type of installations.
The tariffs are regularly adjusted to reflect the changes of system prices. There are two schemes, either a guaranteed tariff or an operating support and market price.

Tariffs for 2H 2012:

Guaranteed Purchase:

Power	on buildings or constructions	ground-mounted
< 50 kW	0.198 €/kWh	0.186 €/kWh
50kW < P < 1 MW	0.181 €/kWh	0.171 €/kWh
1 MW< P < 10MW	0.150 €/kWh	0.138 €/kWh

Note: Each year only 5 MW of new ground-mounted systems can receive the FIT.

Operating Support:

Power	on buildings or constructions	ground-mounted
< 50 kW	0.148 €/kWh	0.137 €/kWh
50kW < P < 1 MW	0.132 €/kWh	0.122 €/kWh
1 MW< P < 10MW	0.099 €/kWh	0.087 €/kWh

Spain

In January 2012, the Spanish Government passed the Royal Decree 1/12 [GoS 2012], which suspended the remuneration pre-assignment procedures for new renewable energy power capacity.
In September 2012, the Spanish Government approved a Draft Bill to curb the electricity budget deficit and includes a flat tax for all electricity generating technologies, including solar PV, of 6%.

Sweden

In 2009, Regulation N° 2009:689 on State Subsidies for Solar Cells went into force. The support is limited to actions commenced on, or after, 1 July 2009 and completed by 31 December 2012. The aid may not exceed 45% of the eligible costs (planning and labour, material). Generally, the subsidy must not exceed 1.5 million SEK (€0.16 million[24]) per photovoltaic system or solar electricity and solar thermal hybrid systems. The total budget for the scheme for 2012 is SEK 60 million (€ 6.6 million).
Energy tax exemption.

[24] Exchange rate: 1 € = 9.15 SEKF

Switzerland

New feed-in tariff in 2008 for new PV systems and those which became operational after 1 January 2006. The tariff is guaranteed for 25 years and annual tariff revisions are foreseen, depending on cost reduction.

Tariffs since 1 October 2012:

Nominal Power	Ground-mounted	Roof-top	Building-integrated
	[CHF/kWh (€/kWh)][25]		
10 kWp	0.331 (0.276)	0.361 (0.301)	0.428 (0.357)
10 – 30 kWp	0.270 (0.225)	0.294 (0.245)	0.365 (0.304)
30 – 100 kWp	0.248 (0.207)	0.269 (0.224)	0.332 (0.277)
100kWp – 1 MWp	0.231 (0.193)	0.251 (0.209)	0.315 (0.263)
> 1 MWp	0.216 (0.180)	0.235 (0.196)	0.289 (0.241)

On 1 January 2013 a further 8% reduction is foreseen

[25] Exchange rate: 1 € = 1.20 CHF

Turkey

The Turkish Parliament passed the Renewable Energy Law in 2005 and an amendment in 2010, which went into force early 2011 [GoT 2010, 2011].

For PV systems, a feed-in tariff of 0.133 $/kWh (0.102 €/kWh) for ten years was set. In addition, there is a local content rule, which increases this tariff for the first five years between 0.005 and 0.067 $/kWh (0.004 – 0.052 €/kWh), depending on the components of a PV system manufactured in Turkey. For the first 3 years of the scheme (until 31 December 2013) a cap of 600 MW was set.

Ukraine

In 2003, Ukraine passed a Law "On Alternative Sources of Energy" and approved the "Energy Strategy of Ukraine to 2030" in 2006 [GoU 2003]. In 2009 the National Commission for State Regulation in the Sphere of Energy (NERC) set feed-in tariffs. At the end of 2011, the tariffs were as follows:

■ **Ground-mounted systems**	5.05 UAH/kWh (0.465 €/kWh[26])
■ **Roof-top systems over 100 kW**	4.87 UAH/kWh (0.446 €/kWh)
Roof-top systems, below 100 kW	4.63 UAH/kWh (0.427 €kWh)
■	

In July 2012, the Ukraine Parliament adopted in a first reading a Draft Law to introduce changes to the promotion of renewable energies. Besides the introduction of a residential PV system category, the rates of the existing categories will decrease by 16 to 27% to reflect the changes in system prices. From 1 January 2013, a local content rule of at least 30% and 1 January 2014 of 50% will apply and the following tariffs are foreseen:

■ **Ground-mounted systems**	3.40 UAH/kWh (0.339 €/kWh)
■ **Roof-top systems over 100 kW**	3.78 UAH/kWh (0.349 €/kWh)
■ **Roof-top systems, below 100 kW**	3.89 UAH/kWh (0.359 €kWh)
■ **Private roof-top systems up to 16 kW**	4.20 UAH/kWh (0.387 €kWh)

[26]Exchange rate 1€ = 1.085 UAH

Inited Kingdom

New feed-in tariff to be paid for 25 years was introduced on 1 April 2010 and is regularly adapted.

Tariffs from 1 November 2012 on:

Power	
< 4 kW	0.1544 £/kWh[27] (0.182 €/kWh)
4 – 10 kW	0.1399 £/kWh (0.165 €/kWh)
10 – 50 kW	0.1303 £/kWh (0.153 €/kWh)
50 – 100 kW	0.1150 £/kWh (0.135 €/kWh)
100 – 150 kW	0.1150 £/kWh (0.135 €/kWh)
150 – 250 kW	0.1100 £/kWh (0.129 €/kWh)
0.25 – 5 MW	0.0710 £/kWh (0.084 €/kWh)
Stand-alone systems	0.0710 £/kWh (0.084 €/kWh)

In addition, there is the possibility to receive Renewable Obligation Certificates (ROC) – for PV the rate is 2 ROCs per MWh – until April 2013.

[27]Exchange rate: 1 € = 0.85 GBP

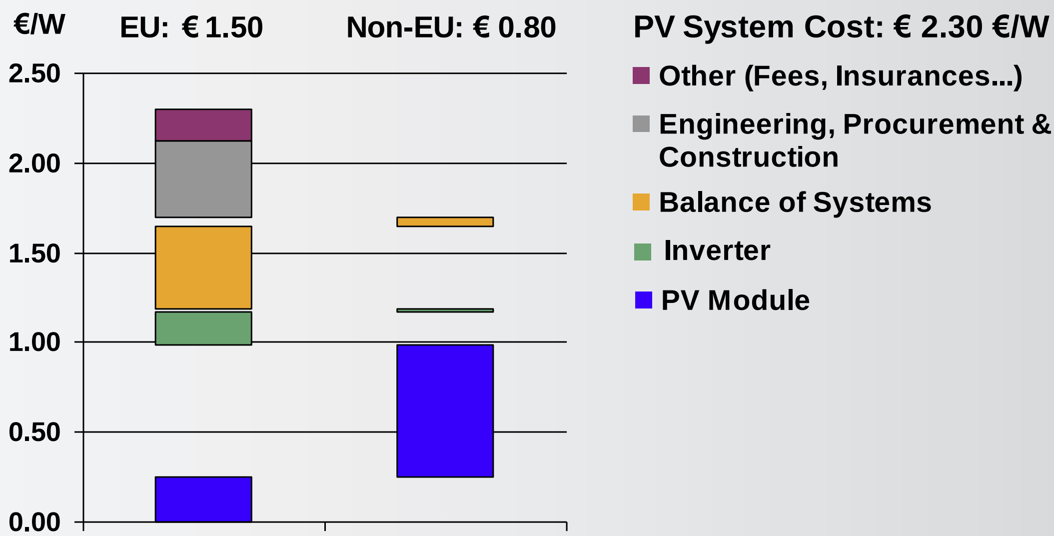


Fig. 12: Breakdown of PV system costs [Oss 2012]

In mid 2012, the residential PV system price in Italy was given at 2,300 €/kWp, about the same as the 2011 average in Germany [Blo 2012c, Bsw 2012, Mer 2012]. The cost breakdown of the 2.3 €/Wp system costs per Wp are as follows (Fig. 12): €0.99 module, €0.2 inverter, €0.51 balance of system (BoS), €0.42 engineering, procurement & construction, €0.18 (others, e.g. fees, insurance, etc.). For the module costs, it was assumed that even if the modules are imported, about 25% of the module cost can be attributed to the European made manufacturing equipment, materials production like polysilicon or ingot/wafer production, conductive pastes, etc. For inverters and the BoS, a European share of 90% was estimated. With these assumptions, the European value in the PV system costs was calculated at 65% or 1.50 €/Wp. With these assumptions, the European value in the PV system costs was calculated at 65% or 1.50 €/Wp.

Under the following assumptions, 2,300 €/Wp system price, electricity generation of 1,000 kWh/kWp installed, 5% capital cost or gain, 20 years of financial lifetime, and 1% O&M costs the Levelised Cost of Energy (LCOE) for the first 20 years was 0.185 €/kWh. One might argue that this is too high a price for the electricity market, where wholesale electricity prices at the electricity exchange are in the order of 60 to 80 €/MWh. However, if one compares the LCOE of PV-generated electricity to the different retail prices European households pay, the findings are astonishing. The competitiveness of PV electricity is mainly determined by the actual electricity retail price and less by the solar resource available (Fig. 13).

In addition, it should be noted that after 20 years, the investment in the PV system has generated the same amount as a normal investment with 5% return, and from then on the LCOE from the PV system would drop to 0.023 €/kWh to cover the O&M costs and would be more than competitive with bulk power prices.

As depicted in Figure 13, in all those European countries which are coloured white to red, PV generated electricity is already cost-competitive or provides a benefit compared to the household retail prices, if all the generated electricity is consumed at the place of generation.

It is interesting to note that the competitiveness of PV electricity in Ireland and Greece is about the same, despite the significant differences in solar radiation.
In those countries where the price difference between the retail price and the PV generation costs exceed 0.05 €/kWh, this opens the possibility for new business models, including storage options in the longer term.

Stable political and socio-economically viable frame conditions do not only convince private and commercial investors to install photovoltaic power plants, but also stimulate the investment in new manufacturing capacities along the whole value chain, from raw materials to system components. As the PV industry is becoming more and more a global industry, Europe had to realise that just because it is an environmental technology, this did not protect it from global competition. Like any other industry, world-wide competition is an essential in the PV industry as well, and if Europe wants to safeguard a vital PV industry it needs to act not in a protectionist way, but to design industry policies, which help and allow European manufactures to be competitive on the world market. So far, a PV Industry Policy is missing on the European, as well as on the national, level.

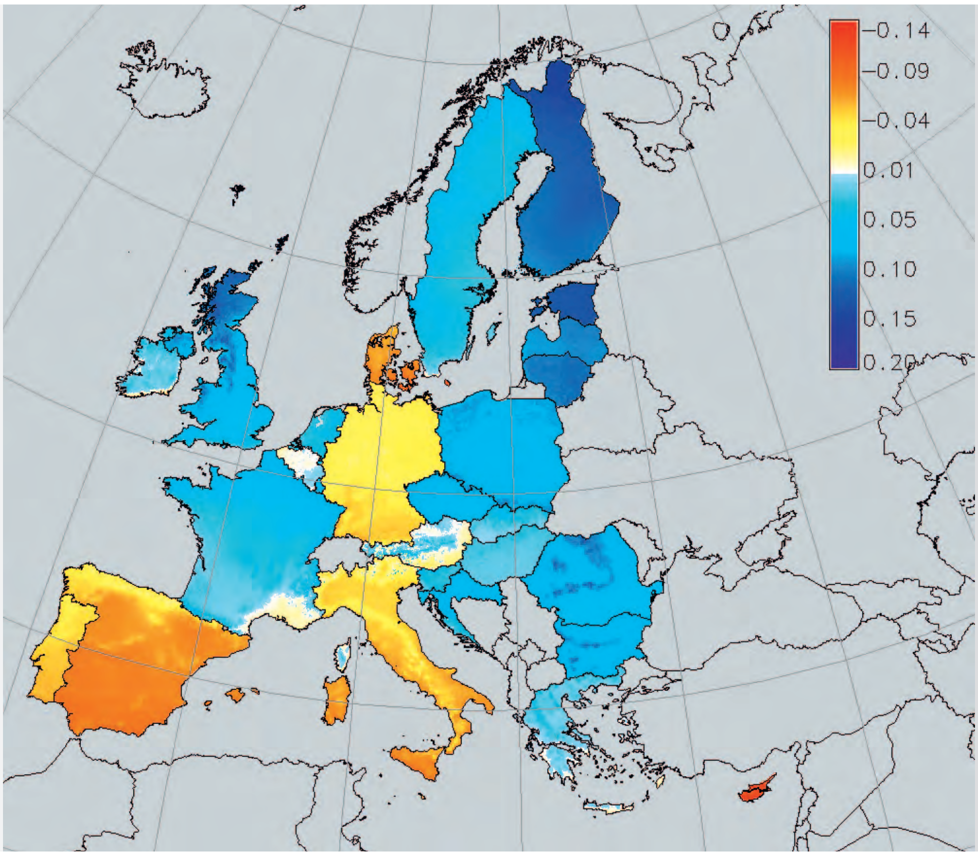


Fig. 13:
Difference between reference PV electricity price and household retail prices in the European Union

Despite the fact that the share of European-made solar cells and modules has decreased to less than 9% in 2011, the European PV industry is still very well positioned along the whole value chain, especially in the equipment manufacturing part, the inverter manufacturing, project businesses, and last but not least research and development.

Based on information provided by the industry, the Energy [R]evolution Study has estimated that, on average, 18 full-time equivalent (FTE) jobs are created for each MW of solar power modules produced and installed [Gre 2012]. This is a significant reduction from the figures (about 45 FTE) a few years ago, which reflects the increased industrialisation of the PV industry. Based on this data, as well as Bloomberg New Energy Finance info the employment figures in the photovoltaics sector for 2011 are estimated around 750,000 world-wide and about 275,000 in the European Union [Blo 2012d].

In March 2011, the European Commission published a Communication to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions entitled ***"A Roadmap for moving to a competitive low carbon economy in 2050"*** [EC 2011]. In this Communication, the significance of early investments into low-carbon technologies was highlighted:

Investing early in the low carbon economy would stimulate a gradual structural change in the economy and can create in net terms new jobs both in the short- and the medium-term. Renewable energy has a strong track record in job creation. In just 5 years, the renewable industry increased its work force from 230 000 to 550 000.… In the longer-term, the creation and preservation of jobs will depend on the EU's ability to lead in terms of the development of new low carbon technologies through increased education, training, programmes to foster acceptability of new technologies, R&D and entrepreneurship, as well as favourable economic framework conditions for investments. In this context, the Commission has repeatedly emphasised the positive employment benefits if revenues from the auctioning of ETS allowances and CO_2 taxation are used to reduce labour costs, with the potential to increase total employment by up to 1.5 million jobs by 2020.

Electricity generated with renewable energy sources, including photovoltaic systems, has additional positive benefits for the European economy in the long run. First, with increasing installations of photovoltaic systems, the electricity generated can help to reduce the import dependency of the European Union on energy imports. In 2010, the energy import dependency of the European Union was 52.68% and without renewable energy it would have been 62.18% [Est 2012]. In the same year, the European Union paid about 2.8% of its GDP or € 350 billion for energy imports. Without the total renewable energy share of 9.5% of primary energy supply (TPES) the bill for energy imports would have been € 33 billions more. This calculation does not even take into account that electricity generated from non-combustible renewable energy sources actually substitute 2.5 to 3 primary energy units per electricity unit generated.

In its World Energy Outlook 2011, the IEA stated that each increase of the oil price by 10 $/bbl would increase the energy bill for the European Union by 0.2% of the GDP [IEA 2011a]. Already in 2005, the results of an impact assessment of the European Commission on the effectiveness of support measures for renewable energies in the European Union stated [EC 2005]:

Rising oil prices and the concomitant general increase in energy prices reveal the vulnerability and dependency on energy imports of most economies. The European Commission's DG ECFIN predicts that a $10/bbl oil price increase from $50 to $60/bbl would cost the EU about 0.3% growth and the US 0.35% [EC 2005a]. For the European Union, the negative GDP effect would be in the order of € 41.9 billion from 2005 to 2007.

It is obvious that further price increases worsened the situation, and some economic analysts claim that the 2008/2009 economic crisis could be attributed to the rapid increase of the oil prices since 2003 and the spike in July 2008[28] [IEA 2008].

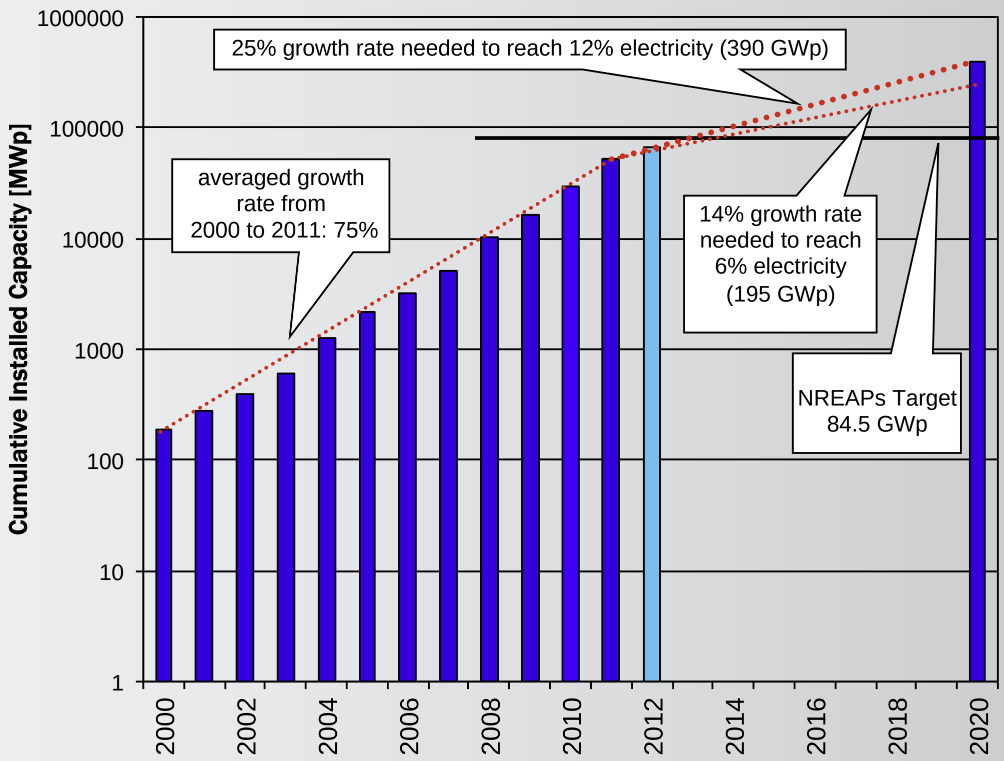
There are several studies that examine the difficult issue of quantifying the effect of the inclusion of RES in an energy portfolio and the reduction in the portfolio energy price. This is in addition to the employment benefits and the economic benefits of avoided fuel costs and external costs (GHG), money which could be spent within the economy and used for local wealth creation [Awe 2003].

A prerequisite for the further growth of renewable and solar energy use is that electricity generated by renewable and solar systems can be freely traded and attain preferential grid access. As PV systems contribute to the avoidance of climatically harmful greenhouse gases, it has to be ensured that electricity generated from solar systems be exempt from eco taxes, where applicable. In addition, one has to enable PV system operators to sell Green Certificates to CO_2-producers.

In 2013, the European Union will probably reach the PV target set in the NREAPs for 2020. The average annual growth rate between 2000 and 2011 was 75%, which is three times the 25% needed between 2011 and 2020 in order to reach 12% of European electricity supply from solar photovoltaic systems (Fig. 15). The main issue to

[28] Crude oil prices went up from US$26/bbl (June 2003) and spiked at US$147.27/bbl (July 2008), source: Oil report IEA

Fig. 14:
PV growth in the European Union and estimate for 2012.



realise such ambitious targets is not whether or not the PV industry can supply the needed systems, but whether or not the electricity grid infrastructure will be able to absorb and distribute the solar-generated electricity. As already mentioned, the fact that LCOE of PV electricity in some countries are already below household retail prices, this opens up the possibility for new business models, including local storage options.

The European PV Industry along the value chain has to work hard to preserve a manufacturing base in Europe, as well as develop new system solutions, including local and central storage solutions to ensure the possibility to allow for higher percentages of PV electricity in the existing grids. This will only be achieved if reliable political framework conditions are created, and maintained, to enable return on investment for investors and the industry alike. Besides this political issue, targeted technology improvements along the whole range of the value chain, are still required.

4.2 PV Research in Europe

In addition to the 27 national programmes for market implementation, research and development, the European Union has been funding research (DG RTD) and demonstration projects (DG TREN) with the Research Framework Programmes since 1980. Compared to the combined national budgets, the EU budget is rather small, but it plays an important role in creating a European Photovoltaic Research Area. This is of particular interest and importance, as research for photovoltaics in a number of Member States is closely linked to EU funds. A large number of research institutions from small university groups to large research centres, covering everything from basic material research to industry process optimisation, are involved and contribute to the progress of photovoltaics. In the following, only activities on the European level are listed, as the national or regional activities are too manifold to be covered in such a report.

The European Commission's Research and Development activities are organised in multi-annual Framework Programmes (FP), originally with a duration of four years. Support for Photovoltaic Research Projects started in the 1980s. In FP4 (1994 to 1998) 85 projects were supported with a budget of € 84 million. In FP5 (1998 to 2002) the budget was increased to around € 120 million and about 100 projects received funding. In FP6 (2002 to 2006) the budget for PV projects fell to € 107.5 million. An overview about the FP6 funded projects was published by the European Commission in 2009 [EC 2009a].

In addition to these technology-oriented research projects, there were Marie Curie Fellow-ships and the "Intelligent Energy – Europe" (EIE) Programme. The CONCERTO Initiative, launched by the European Commission, was a Europe-wide Initiative proactively addressing the challenges of creating a more sustainable future for Europe's energy needs. CONCERTO is supervised by DG Energy and Transport and made available € 14 million for solar-related projects.

During the 6th Framework Programme, the PV Technology Platform was established. The aim of the Platform is to mobilise all the actors sharing a long-term European vision for photovoltaics. The Platform developed the European Strategic Research Agenda for PV for the next decade(s) and the corresponding implementation plan to ensure that Europe maintains industrial leadership [Ptp 2007, 2009].

For the first time, the **7th EC Framework Programme** for Research, Technological Development has a duration of seven years and runs from 2007 to 2013. The Commission expects the following impacts from the research activities: *Through technological improvements and economies of scale, the cost of grid-connected PV electricity in Europe is expected to be lowered to a figure in the range of 0.10 - 0.25 €/kWh by 2020. Research and development should lead to reduced material consumption, higher efficiencies and improved manufacturing processes, based on environmentally sound processes and cycles.*

The following projects have been approved since the publication of the 2011 PV Status Report [Jäg 2011].

The EU-Japan Coordinated Call addressing *Ultra-high efficiency concentration photovoltaics (CPV) cells, modules and systems* has resulted in the project NGCPV, 42-month duration for an EU contribution of € 5 million. NGCPV, coordinated by Universidad Politecnica de Madrid, Spain, pursues the improvement of present concentration cells, modules and system efficiency, and envisages the construction of a 50 kW concentration plant as a means of field demonstration. A special effort is being devoted to the development of multi-junction cells by making use of e.g. inverted and bifacial growth, and incorporation of quantum nanostructures. Targeted efficiencies are 50% at the cell level and 35% at the module level.

The FP7 2011 call topic on *Productivity and cost optimisation issues for the manufacturing of photovoltaic systems based on concentration* has resulted in the selection of two project proposals, *CPV4ALL* and *ECOSOLE*.

In September 2012, the *CPV4ALL* grant agreement had not been signed yet. Voestalpine Automotive GMBH coordinates the project which is focused on demonstrating and validating, at industrial scale, the production technology for the components and the assembly technology for the photovoltaic modules and system based on solar concentration. The project's total cost is € 12.6 million and the EU grant is about € 7.3 million.

The project ECOSOLE is focused on the realisation of innovative photovoltaic generator based on solar concentration and the demonstration of new and more efficient methods for large-scale, low-cost manufacturing of related modules and systems. The project, coordinated by Becar Srl (Beghelli Group), has a total eligible cost of about €12 million and an EU grant of almost €7 million.

The FP7 2011 call topic on *Development and demonstration of standardised building components based on photovoltaics* has resulted in the selection of two project proposals, *BFIRST* and *CONSTRUCT PV.*

The project BFIRST deals with design, development and demonstration of a portfolio of innovative photovoltaic products for building integration, based on cell encapsulation within fibre-reinforced composite materials. The aim is to expand the portfolio of photovoltaic products which are currently available, with new standardised solutions developed to a pre-industrial stage. The project, coordinated by Tecnalia, has a total cost of about €5.4 million and receives an EU grant of € 3.3 million.

In September 2012, the grant agreement concerning the project proposal *CONSTRUCT PV* had not been signed yet. The project aims to develop and demonstrate customisable, efficient, and low-cost building integrated photovoltaic solutions for opaque surfaces of buildings. The proposal, coordinated by ZUEB, foresees a total cost of about € 11.7 million and an EU grant of € 6.9 million.

Finally, three projects have received a grant under the joint call between the Theme "Energy" and the Theme on "Nanosciences, Nanotechnologies, Materials and New Production Technologies" (NMP), which addressed the topic *Development and up-scaling of innovative photovoltaic cell processes and architectures to pilot-line scale for industrial application.*

The project FAST TRACK, with an EU contribution of € 9.3 million, coordinated by the Forschungszentrum Juelich Gmbh in Germany, focuses on bringing the next-generation thin-film silicon (TfSi) technology to the market, using newly developed state-of-the-art knowledge to solve the complex puzzle of achieving, at the same time, strong light in-coupling (high current) and good electrical properties (open-circuit voltage and fill factor). The target of the project is to achieve solar cells with 14% stable efficiency, leading to the demonstration of reliable production size prototype modules of 12% level.

The project R2R-CIGS, with an EU contribution of €7 million, coordinated by the Nederlandse Organisatie voor Toegepast Natuurwetenschappelijk Onderzoek – TNO, in the Netherlands, aims to develop efficient flexible solar modules by implementing innovative cost-effective processes, so that production costs below 0.5 €/W could be achieved in large volume factories with annual capacity of 500 MW in the future.

The project SCALENANO, with an EU contribution of €7.5 million, coordinated by Fundacio Institut de Recerca de l'Energia de Catalunya, in Spain, will exploit the potential of chalcogenide based thin-film photovoltaic technologies, for the development and scale-up of new processes based on nano-structured materials for the production of high-efficiency and low-cost photovoltaic devices and modules compatible with mass production requirements.

The work programme for the FP7 2012 calls was published on 20 July 2011. Two topics for collaborative projects with a predominant demonstration component were published, namely:

1. Reliable, cost-effective, highly performing PV systems (deadline: 25/10/2011) and 2. Demonstration of smart multi-functional PV modules (deadline: 08/03/2012).
The evaluation of the proposals received under both topics has been completed. Two proposals under the first topic have been retained for negotiations, for an estimated total contribution of about €7.6 million. Three proposals under the second topic have been retained for negotiation, for an estimated total contribution of about €9 million.

In addition, the FP7 2012 call topic on *Future Emerging Technologies* (FET), with deadline on 25/10/2011, has also resulted in the selection of two PV proposals which have been retained for negotiation – currently underway – for an overall EU contribution of about €5.0 million.

Furthermore, the FP7 2012 topic *ERA-NET on Solar Electricity: Implementation of the Solar Energy Industry Initiative* (deadline: 28.02.2012) has resulted in the selection of one proposal, currently under negotiation, which will be granted an EU contribution of about € 2.0 million.

The FP7 2013 calls for proposals have been published on 10 July 2012. Three main PV topics are addressed:

- *High efficiency c-Si photovoltaics modules* (call: FP7-ENERGY-2013-1; topic ENERGY.2013.2.1.1 - deadline: 28/11/2012),

- *Support to key activities of the European Photovoltaics Technology Platform* (TP PV) (call: FP7-ENERGY-2013-IRP; topic ENERGY.2013.2.1.2 – deadline: 08/01/2013), and

- *Integrated research programme in the field of photovoltaics* (call: FP7-ENERGY-2013-IRP; topic ENERGY.2013.10.1.5 – deadline: 08/01/2013).

4.2.1 The Strategic Energy Technology Plan

On 22 November 2007, the European Commission unveiled the European Strategic Energy Technology Plan (SET-PLAN) [EC 2007a]. The SET-Plan should focus, strengthen and give coherence to the overall effort in Europe, with the objective of accelerating innovation in cutting edge European low carbon technologies. In doing so, it will facilitate the achievement of the 2020 targets and the 2050 vision of the Energy Policy for Europe. The Communication on the SET-Plan states:

Europe needs to act now, together, to deliver sustainable, secure and competitive energy. The inter-related challenges of climate change, security of energy supply and competitiveness are multifaceted and require a coordinated response. We are piecing together a far-reaching jigsaw of policies and measures: binding targets for 2020 to reduce greenhouse gas emissions by 20% and ensure 20% of renewable energy sources in the EU energy mix; a plan to reduce EU global primary energy use by 20% by 2020; carbon pricing through the Emissions Trading Scheme and energy taxation; a competitive Internal Energy Market; an international energy policy. And now, we need a dedicated policy to accelerate the development and deployment of cost-effective low carbon technologies.

In June 2009, the European Photovoltaic Industry Association published its study *"SET for 2020 – Solar photovoltaic Electricity: A mainstream power source in Europe by 2020"* [Epi 2009]. The study explores different deployment scenarios ranging between 4 and 12%.

4.2.2 Solar Europe Industry Initiative

Within the SET-Plan, photovoltaics was identified as one of the key technologies and the SET-Plan calls for six different European Initiatives, one of them being solar. ***The Solar Europe Industry Initiative*** (SEII) has two pillars: photovoltaics and concentrated solar thermal power. The Initiative focuses on large-scale demonstration for both technologies and was officially launched at the beginning of June 2010, under the Spanish Presidency.

The intention of the SET-Plan Initiatives is that they are industry-led, and for this reason the European Photovoltaic Industry Association (EPIA) developed an implementation plan for the first three years of the PV part of the Solar Europe Industry Initiative [Sei 2010].

The Implementation Plan of the SEII clearly identifies the recommended actions and investment areas, their budgetary implications and the resulting expected measurable benefits for the European society. Within SEII it is envisaged to achieve the following three strategic objectives:

- SEII will bring PV to cost competitiveness in all market segments (residential, commercial, and industrial) by 2020 (cost reduction);
- SEII will establish the conditions allowing high penetration of distributed PV electricity within the European electricity system (integration);
- SEII will facilitate the implementation of large-scale demonstration and deployment projects with a high added value for the European PV sector and society as a whole.

In addition to this, the SEII creates the necessary basis for development beyond 2020 and the 2020 targets, supporting the European industry to also play a leading role in the longer term.

4.3 Solar Companies

In the following, some European solar cell manufacturers, not yet mentioned in Chapter 3, are described briefly. This listing does not claim to be complete, especially concerning the great number of start-up companies. In addition, it has to be noted that information or data for some companies are very fragmented and limited. A lot of the data were collected from the companies' web-sites.

4.3.1 AVANCIS GmbH & Co KG (Germany)

AVANCIS was founded as a joint venture between Shell and Saint-Gobain in 2006. In 2008, commercial production started in the new factory with an initial annual capacity of 20 MW in Torgau, Germany. In 2009, Saint-Gobain took over the shares of Shell and started the construction of a second CIS factory with a total capacity of 100 MW in

Torgau. In October 2010, the company announced the forming of a joint venture with Hyundai Heavy Industries (HHI), in Korea, for the production of CIS solar cells with a production capacity of initially 100 MW. Production in 2011 is reported with 20 MW [Pho 2012].

4.3.2 Bosch Solar (Germany)

The Bosch Group, a leading global supplier of technology and services in the areas of automotive and industrial technology, consumer goods, and building technology, took over the 1997 founded ErSol Solar Energy AG Erfurt in 2008 and renamed it Bosch Solar. Bosch Solar manufactures and distributes photovoltaic crystalline and thin-film silicon products. In 2011, the company had a production of 450 MW [Pho 2012] and a production capacity of 710 MW. In spring 2011, Bosch Solar announced that they would build a new 150 MW module manufacturing plant in Vénisseux, France. In 2012 the company put the construction of a new manufacturing site for cells and modules with 630 MW in Malyasia on hold and decided to stop its production of thin-film silicon solar cells.
Bosch Solar holds a 35% interest in the joint venture company Shanghai Electric Solar Energy AG Co. Ltd., Shanghai, People's Republic of China (SESE Co. Ltd.), which was established in 2005 and has been producing solar modules since 2006. In 2009, Bosch Solar also acquired 68.7% of the German module manufacturer Aleo Solar AG and took over the majority of the German CIS company Johanna Solar GmbH.

4.3.3 Inventux Technologies AG (Germany)

Inventux was founded in spring 2007 to manufacture amorphous/microcrystalline thin-film silicon solar modules and broke ground for its 40 MWp factory in Berlin, Germany, in September 2007. Commercial production started at the end of 2008. For 2011, a production of 60 MW is reported [Pho 2012]. In May 2012 the company filed for insolvency and was finally taken over by a group of South American investors.

4.3.4 Isofotón (Spain)

Isofotón, a private-owned company, was set up in Malaga to produce silicon solar cells by Professor Antonio Luque from the Universidad Politécnica de Madrid. In 1985, Isofotón expanded their activities in the solar sector and also started to fabricate solar collectors. In 2010, Isofotón acquired a new investor and owner: the consortium Affirma-Toptec. The company announced that it would increase its production capacity from 140 MW to 230 MW in 2011 and build a new module factory with a capacity of 50 MW in Ohio, USA, which was opened in September 2012. About 80 MW of production were reported for 2011 [Pho 2012].
In August 2012, the company announced that it had received a €40 million loan from SAMSUNG and € 8.4 million from the Andalusian Government. The company plans to increase production capacity up to 1.5 GW in the next two years.
Besides silicon solar cells and modules, Isofotón is very active in developing flat-panel concentrator systems, based on GaAs solar cells. This kind of system is favourable for areas with a high proportion of direct sunlight and for large-scale solar plants.

4.3.5 Masdar PV (Germany/UAE)

Masdar PV was founded in 2008 by the Masdar Initiative, which is driven by the Abu Dhabi Future Energy Company (ADFEC), a fully-owned company of the Government of Abu Dhabi, through the Mubadala Development Company. The company broke ground on a 40 MW a-Si thin-film plant, Ichtershausen (Thuringia), Germany, the same year and started commercial operation in 2009. At the end of 2011, the capacity of the plant was 75 MW. In 2011, 35 MW of actual production is reported [Pho 2012].

4.3.6 Photowatt (France)

Photowatt was set up in 1979 and relocated to Bourgoin-Jallieu, France, in 1991, where the company converts silicon waste into the raw material used for the manufacturing of solar energy cells. At the beginning of 1997, Matrix Solar Technologies, a subsidiary of the Canadian company, ATS (Automation Tooling Systems), acquired Photowatt International and started to expand the production capacities. In 2010, the company opened a 100 MW module plant in Ontario, Canada. EDF Énergies NouvellesRéparties has owned the company since 1 March 2012. In 2011, Photowatt had a production capacity of 75 MW and actual production of 51 MW [Pho 2012].

4.3.7 Photovoltech (Belgium)

Photovoltech was set up in 2002 by Total, Electrabel, Soltech and IMEC, for the manufacturing and world-wide marketing of photovoltaic cells and modules. It is located in Tienen, Belgium, and uses the most advanced IMEC technology.
In 2011, the company had a production of 150 MW and actual production of 116 MW polycrystalline solar cells [Pvn 2012].

4.3.8 Schott Solar AG (Germany)

Schott Solar AG has been a fully-owned subsidiary of Schott AG, Mainz, since 2005, when Schott took over the former joint venture RWE-Schott Solar, except for the Space Solar Cells Division in Heilbronn. Schott Solar's portfolio comprises crystalline wafers, cells, modules and systems

for grid-connected power and stand-alone applications, as well as a wide range of ASI® thin-film solar cells and modules. In 2011, the company had a production capacity of 340 MW and an actual production of 295 MW [Pvn 2012]. However, in June 2012 the company announced that it was stopping the production of crystalline silicon solar cells and modules due to the world-wide overcapacity and price pressure. Thin-film manufacturing is not affected by this decision.
Development of amorphous silicon solar cells started at MBB in 1980. Phototronics (PST) was founded in 1988. In 1991, one of the world's first large-area pilot production facilities for amorphous silicon was built. In January 2008, the company started shipments of modules from its new 33 MW manufacturing facility for amorphous silicon thin-film solar modules in Jena, Germany.

4.3.9 Schüco Dünnfilm GmbH & Co. KG (Germany)

Schüco Thin-film GmbH & Co. KG is a subsidiary of Schüco International KG and was founded in 2008, under the name Malibu. In 2009, the company opened its a-Si thin-film plant with 40 MW production capacity. In 2010, it took over the 60 MW a-Si factory of the insolvent Sunfim AG in Großröhrsdorf, Germany. For 2011, a production of 50 MW is reported [Pho 2012]. Due to the fierce price competition and world-wide overcapacities the company decided to end production at the end of September 2012.

4.3.10 Solar Cells Hellas Group S.A. (Greece)

Solar Cells Hellas was founded in 2006, and started commercial production with a 30 MW capacity in 2008. The capacity for wafers and solar cells was gradually increased and reached 80 MW at the beginning of 2010. Module production capacity reached 110 MW in February 2011. In 2011, the company had a solar cell production of 27 MW [Pho 2012].

4.3.11 Solar World AG (Germany/USA)

Since its founding in 1998, Solar World has changed from a solar system and components dealer to a company covering the whole PV value chain, from wafer production to system installations. The company now has manufacturing operations for silicon wafers, cells and modules in Freiberg, Germany, and Hillsoboro (OR), USA. Additional solar module production facilities exist in Camarillo (CA), USA, and since 2008 with a joint venture between Solarworld and Solar-Park Engineering Co. Ltd. in Jeonju, South Korea.
At the end of 2011, production capacities were as follows: 1 GW wafers (250 MW USA, 750 MW Germany), 850 MW solar modules (350 MW USA, 500 MW Germany) and 800 MW solar cell (500 MW USA, 300 MW Germany). Total cell production in 2011 is reported as 425 MW, with 250 MW coming from Germany and 275 MW from the USA [Pho 2012].
In 2003, the Solar World Group was the first company world-wide to implement silicon solar cell recycling. The Solar World subsidiary Deutsche Solar AG commissioned a pilot plant for the reprocessing of crystalline cells and modules.

4.3.12 Soltecture Solartechnik GmbH (Germany)

Soltecture was founded as Sulfurcell Solartechnik GmbH, in June 2001, and is jointly owned by its founders and investing partners. In 2004, the company set up a pilot plant to scale up the copper indium sulphide (CIS) technology, developed at the Hahn-Meitner-Institut, Berlin. First prototypes were presented at the 20th PVSEC in Barcelona in 2005. Production of CIS modules started in December 2005 and in 2006 the company had sales of 0.2 MW. The first 35 MW expansion phase was completed in October 2009 and for 2010 a production of 14 MW is reported [Pvn 2012]. In May 2012 the company filed for insolvency and despite various rumours no take over has been officially confirmed so far.

4.3.13 Solland Solar Energy BV (The Netherlands/Germany)

Solland Solar is a Dutch-German company and was registered in 2003. At the end of 2004 the construction of the factory went underway and start-up of production took place in September 2005. At the end of 2007, production capacity was 60 MW and increased to 170 MW in the first half year of 2008. Solland had a production of 75 MW in 2011 [Pvn 2012]. The solar cell manufacturing part of the company was sold in January 2012 to the Italian Pufin Group.

4.3.14 Sovello AG (Germany)

Sovello opened its first factory to produce 30 MW String-Ribbon™ wafers, solar cells and solar modules in Thalheim, Germany, in 2006. The second factory, with 60 MW capacity, was added in 2007 and in total capacity reached 180 MW in 2009. In 2010, Sovello had a production of 180 MW [Pho 2012]. After the company filed for insolvency in May 2012, the production was shut down in August 2012.

4.3.15 Sunways AG (Germany)

Sunways AG was incorporated in 1993 in Konstanz, Germany, and went public in 2001. Sunways produces polycrystalline solar cells, transparent solar cells and inverters for PV systems. Sunways opened its second production facility with an initial production capacity of 30 MW in Arnstadt, Germany, in 2005, which was expanded to 100 MW in 2008. Total production capacity in 2011 was 116 MW. In 2011, the company produced 62 MW [Pho 2012].

In the first half of 2012, the company was acquired by LDK Solar Germany Holding GmbH, which is an indirect subsidiary of LDK Solar Co., Ltd. (PRC)

4.3.16 Additional Solar Cell Companies

- **Calyxo GmbH** was founded as a subsidiary of Q-Cells AG, located in Wolfen, Saxony-Anhalt, Germany. In February 2011, Solar Fields, LLC took over the ownership from Q-Cells. In 2008, the company started to manufacturer CdTe thin-film solar cells with a pilot 25 MW and started an 85 MW expansion project, which should be fully operational at the end of 2012. About 7 MW of CdTe modules were manufactured in 2011 [Pho 2012].

- **Concentrix Solar GmbH** was founded in 2005 as a spin-off company of Fraunhofer Institute for Solar Energy Systems and is located in Freiburg/Breisgau, Germany. Under the brand name FLATCON®, complete, turnkey concentrator photovoltaic power plants on the commercial level are offered. From 2006 until August 2008, the company manufactured its concentrator modules on a pilot production line, before a commercial production line with 25 MW capacity started operation in September 2008. In December 2009, the French Soitech Group acquired Concentrix.

- **G24 Innovations Limited (G24i)**, headquartered in Cardiff, Wales, manufactures and designs solar modules based on Dye Sensitised Thin-Film (DSTF) technology. In 2007, production of dye-sensitised solar cells, with a roll-to-roll process, started. First commercial sales took place in 2009.

- **Helios Technologies** located in Carmignano di Brenta (PD), Italy, was established in 1981 and became a part of the Kerself Group in 2006. It manufactures solar cells, modules and photovoltaic systems. Current production capacity is 60 MW for solar cells and 50 MW for modules. For 2011, a production of 41 MW is reported [Pho 2012].

- **Odersun AG** was founded in 2002 and developed a unique thin-film technology for the production of copper indium sulphide-based solar cells. The main investor is Doughty Hanson Technology Ventures, London, and the company has signed an agreement with Advanced Technology & Materials Co. Ltd., which is listed on the Shenzhen Stock Exchange to cooperate, in August 2004. The first production line was inaugurated on 19 April 2007. For 2011, 18 MW of production is reported [Pho 2012]. The company filed for insolvency in March 2012 and terminated operation at the end of June 2012.

- **Pramac Ecopower** is a division of the Pramac SpA Group, located in Balerna (Chiasso), Switzerland. The company manufactures mono- and polycrystalline modules and started with the production of amorphous/microcrystalline thin-film solar modules at their 30 MW factory in July 2009. For 2011, 15 MW of production is reported [Pho 2012].

- **SOLARTEC sro.** was established in 1993 and is located in the industrial area of Roznov pod Radhostem, in the eastern part of the Czech Republic. The company is a producer of solar cells and modules, as well as a PV system integrator. According to the company it has a production capacity of 5 MW.

- **Solsonica s.p.A.,** located in Cittaducale (RI), Italy, is a subsidiary of EEMS and was set up in 2007. In 2008, the company started commercial production of polycrystalline silicon cells and photovoltaic modules (initial installed capacity: 30 MW for cells, 40 MW for modules). For 2011, a production of 13 MW is reported [Pho 2012].

- **T-Solar Global, S.A.** (T-Solar) was founded in October 2006. In October 2009, a factory with an initial production capacity of 40 MW, was inaugurated in Ourense, Spain. The production plant is based on technology from Applied Materials. For 2011, a production capacity of 61 MW, and actual production of 38 MW, is reported [Pho 2012].

- **VHF Technologies SA** (Flexcell) is located in Yverdon-les-Bains in Switzerland and produces amorphous silicon flexible modules on plastic film, under the brand name "Flexcell". The first production line on an industrial scale of 25 MW became operational in 2008.

4.3.17 Elkem AS (Norway)

Elkem has been a subsidiary of the China National Bluestar Group Co., Ltd. since April 2011. Elkem Solar developed a metallurgical process to produce silicon metal for the solar cell industry. Elkem is industrialising its proprietary solar grade silicon production line at Fiskaa in Kristiansand, Norway. According to the company, the first plant at Fiskaa has a capacity of 6,000 tons of solar grade silicon and was opened in 2009. In September 2012, the company announced a temporary close down of its production.

4.3.18 Leybold Optics Solar (Germany)

Leybold Optics is one of the leading providers of vacuum technology, headquartered in Alzenau, Germany. Since 2001, the company has been owned by the Private Equity Fund EQT. Leybold Optics Solar designs manufactures and installs complete production systems for the manufacturing of thin-film single junction a-Si and a-Si/µc-Si tandem solar modules, along with the total project support. In addition, they offer various kinds of production equipment for the solar industry. The company was acquired by Bühler (Switzerland) in 2012.

4.3.19 Manz Automation AG (Germany)

Manz is headquartered in Reutlingen, Germany, and was established in 1987. In 2002, they entered the solar business and delivered their first automation system for fully automated crystalline solar cell manufacturing lines. Next was the development of fully automated quality testing and sorting systems for crystalline solar cells. In the summer of 2010, Manz signed a **cooperation agreement with Würth Solar,** Schwäbisch Hall, Germany, that gives Manz access to exclusive know-how in CIGS thin-film technology and completely took over the innovation CIGS line on 1 January 2012. The company is also active in equipment manufacturing for the Flat Panel Display industry, as well as the production equipment for Li-ion batteries. The company opened a new production facility in Suzhou, China, at the end of 2011.

4.3.20 Meyer Burger Group (Switzerland)

Meyer Burger was founded in 1953 and entered the solar business in 1998 with the development of a dedicated band saw for solar wafer mass production. In 2010, the company merged with 3S Industries Ltd., a provider of manufacturing equipment and entire production lines for the manufacturing of solar modules. Core competencies include 3S Swiss Solar Systems Ltd. (laminating), Somont GmbH (electrical cell connection, soldering process) and Pasan SA (testing and measuring of solar cells and modules). In 2011, the company took over from the German equipment manufacturer Roth & Rau to strengthen its offerings in the solar cell process and combine the most important technology steps within the value chain of photovoltaics.

4.3.21 Nitol Solar (Russia)

Nitol Solar was established in 2006 as part of the NITOL Group, with a production facility based in the Irkutsk region in Russia. The production activity is based on two divisions – the Chemical Division and the Polysilicon Division, which produces trichlorosilane (TCS) and polysilicon (PCS). In January 2007, the company commissioned and commenced operation of a 10,000 metric tons per year solar-grade TCS production facility and began selling solar-grade TCS in March 2007. The company planned to increase its solar-grade TCS capacity by 15,000 metric tons per year and the first 5,000 metric tons phase was expected to become fully operational in 2011.

4.3.22 NorSun AS (Norway)

NorSun AS is a subsidiary of the technology group SCATEC AS. The Norwegian start-up company was established in 2005. The construction of a monocrystalline ingots and wafer manufacturing facility in Årdal, Norway, started in 2007 and reached a capacity of over 250 MW. A second ingot plant is located in Vanta, Finland, and is operating with 30 MW. The company is in the development of a 500 MW plant in Singapore for 2013.

4.3.23 OERLIKON Solar (Switzerland)

The cooperation of the Institute of Microtechnology (IMT), the University of Neuchâtel (Switzerland) and UNIAXIS, led to the establishment of UNAXIS Solar. In August 2006, the company changed its name to OERLIKON Solar. UNAXIS Solar started operation on 1 July 2003 with the aim to develop the production technology for large-scale production of PV modules, based on the micromorph solar cell concept developed at IMT and UNAXIS's KAI production systems.
In the meantime, OERLIKON Solar has developed into a supplier of turn-key production equipment for thin-film silicon solar modules. The technology available is for amorphous silicon and amorphous/micromorph tandem cells. In March 2012, the company was acquired by Tokyo Electron (Japan).

4.3.24 PV Crystalox Solar plc (Germany/United Kingdom)

PV Crystalox Solar plc arose from the merger of Crystalox Ltd. in Wantage, near Oxford, UK, and PV Silicon AG in Erfurt, Germany. The product range includes: solar grade silicon; single crystal ingots, single crystal wafers and multicrystalline wafers. The company went public in June 2007 and is listed on the London Stock Exchange. In February 2009, the 1,600 metric tons production facility for solar-grade silicon in Bitterfeld, Germany, was opened. Wafering capacity is given with 750 MW and for 2011 shipments of 384 MW are reported.

5. India

The Indian National Solar Mission or Jawaharlal Nehru National Solar Mission (JNNSM) was initiated by the Government as one of the eight programmes under the National Action Plan for Climate Change by the Prime Minister of India in 2008. In November 2009, the Mission outline was released and the Mission was formally launched by the Prime Minister of India on 11 January 2010. It aims to make India a global leader in solar energy and envisages an installed solar generation capacity of 20 GW by 2020, 100 GW by 2030 and 200 GW by 2050.

In May 2010, the Indian Semicondutor Association (ISA) published a report about the Solar PV Industry and the importance of the Jawaharlal Nehru National Solar Mission for the development of the Indian PV industry and the actual PV system implementation [Isa 2010].

At the end of 2008, most of photovoltaic applications in India were off-grid, mainly solar lanterns, solar home systems, solar street lights and water pumping systems. Grid-connected were 33 solar photovoltaic systems, with a total capacity of approximately 2 MWp. For its 11th Five Year Plan (2008 – 2012), India has set a target to install 50 MW grid-connected photovoltaic systems, supported by the Ministry of New and Renewable Energy, with an investment subsidy and power purchase programme.

5.1 Implementation of Solar Energy[29]

5.1.1 National Solar Mission

The objective of the National Solar Mission is to establish India as a global leader in solar energy, by creating the policy conditions for its diffusion across the country as quickly as possible [GoI 2010].

The Mission will adopt a 3-phase approach, spanning the remaining period of the 11th Plan and first year of the 12th Plan (up to 2012-13) as Phase 1, the remaining four years of the 12th Plan (2013-17) as Phase 2 and the 13th Plan (2017-22) as Phase 3. At the end of each Plan, and mid-term during the 12th and 13th Plans, there will be an evaluation of progress, review of capacity and targets for subsequent phases, based on emerging cost and technology trends, both domestic and global. The aim would be to protect the Government from subsidy exposure, in case expected cost reduction does not materialise, or is more rapid than expected.

The immediate aim of the Mission is to focus on setting up an enabling environment for solar technology penetration in the country, both at a centralised and decentralised level.

[29] Exchange rate: 1 € = 68.9 Rs

The first phase (up to 2013) will focus on the capturing of the low-hanging options in solar thermal; on promoting off-grid systems to serve populations without access to commercial energy and modest capacity addition in grid-based systems. In the second phase, after taking into account the experience of the initial years, capacity will be aggressively ramped up to create conditions for up-scaled and competitive solar energy penetration in the country.

To achieve this, the Mission targets are:

- To create an enabling policy framework for the deployment of 20,000 MW of solar power by 2022.
- To ramp up capacity of grid-connected solar power generation to 1,000 MW within three years – by 2013; an additional 3,000 MW by 2017 through the mandatory use of the renewable purchase obligation by utilities backed with a preferential tariff. This capacity can be more than doubled – reaching 10,000 MW installed power by 2017 or later, based on the enhanced and enabled international finance and technology transfer. The ambitious target for 2022 of 20,000 MW or more, will be dependent on the 'learning' of the first two phases, which if successful, could lead to conditions of grid-competitive solar power. The transition could be appropriately up-scaled, based on availability of international finance and technology.
- To create favourable conditions for solar manufacturing capability, particularly solar thermal for indigenous production and market leadership.
- To promote programmes for off-grid applications, reaching 1,000 MW by 2017 and 2,000 MW by 2022.
- To achieve 15 million square metres solar thermal collector area by 2017 and 20 million by 2022.
- To deploy 20 million solar lighting systems for rural areas by 2022.

The Solar Mission requires that the Tariff Policy be modified to mandate that the Regulators fix a percentage for purchase of power generated using solar energy. The indicated start point percentage is 0.25% in Phase I, to be increased to 3% by 2022.

5.1.2 National Tariff Policy

The existing Tariff Policy from 2006 mandates the State Electricity Regulatory Commissions (SERCs) to fix a minimum percentage of energy purchase from renewable energy sources. Eleven State Regulators have introduced Renewable Energy Purchase Obligations (RPOs) for the State power distribution companies. The RPOs vary considerably amongst States, from as low as 1% in some States to 10% in others. The mandate has been largely fixed on the basis of the relative renewable energy development potential of the State. However, no specific solar obligations were set.

The cumulative solar PV installations exceeded 1 GW at the end of the second quarter 2012. The JNNSM uses a reverse auction, or bidding system, to select projects and the lowest bidder wins. In the first rounds, there were no technical qualification requirements and participants did not need any prior solar project development experience to win a bid. This combination of lacking technical requirements and bidding process has driven solar tariffs to some of the lowest rates in the world, 7 to 10 Rs/kWh (0.102 – $0.145 €/kWh[30]), and which created an extremely difficult situation for the young Indian solar industry [Mer 2012].

5.1.3 Gujarat Tariff Policies

Gujarat, located in western India, receives an average solar radiation between 5.6 – 6 kWh/m^2 per day. Gujarat was one of the first States to establish an agency dedicated to the development of renewable energy in 1979, Gujarat Energy Development Agency (GEDA). In January 2009, the *Gujarat Solar Policy 2009* was passed and it sets a 10% Renewable Purchase Obligation to be achieved by the end of FY2013.

In September 2009, the Gujarat Government signed an MoU with the Clinton Foundation for setting up a 3,000 MW Solar Power Project in Gujart on Government waste-land.

Solar Policy 2009 defined a feed-in tariff for PV and CSP systems. The tariff for PV systems was revised early 2012 and depends on when the systems are commissioned. Rooftop systems up to 1 MW, and ground mounted systems between 0.1 and 1 MW, are applicable for the kWh tariff, whereas ground mounted systems larger than 1 MW are applicable for a MWh tariff. Up to 90% of the capital cost of the PV system can be depreciated over 25 years, during which the feed-in tariff is paid. In addition, PV system owners can opt for a higher depreciation of 6% for the first 10 years and 2% for the following 15 years.

- Between 29 January 2012 and 31 March 2013:

MWh tariff with accelerated depreciation:

Levelised Tariff for 25 years:	9.28 Rs/kWh (0.135 €/kWh)
For the first 12 years	9.98 Rs/kWh (0.145 €/kWh)
For the subsequent 13 years:	7.00 Rs/kWh (0.102 €/kWh)

[30] Exchange rate: 1 € = 68.9 Rs

MWh tariff with normal depreciation:
Levelised Tariff for 25 years: 10.37 Rs/kWh (0.151 €/kWh)
For the first 12 years 11.25 Rs/kWh (0.163 €/kWh)
For the subsequent 13 years: 7.50 Rs/kWh (0.109 €/kWh)

kWh tariff with accelerated depreciation:
11.14 Rs/kWh (0.162 €/kWh)

kWh tariff with normal depreciation:
12.44 Rs/kWh (0.181 €/kWh)

- Between 1 April 2013 and 31 March 2014:

MWh tariff with accelerated depreciation:
Levelised Tariff for 25 years: 8.63 Rs/kWh (0.125 €/kWh)
For the first 12 years 9.13 Rs/kWh (0.133 €/kWh)
For the subsequent 13 years: 7.00 Rs/kWh (0.102 €/kWh)

MWh tariff with normal depreciation:
Levelised Tariff for 25 years: 9.64 Rs/kWh (0.140 €/kWh)
For the first 12 years 10.30 Rs/kWh (0.149 €/kWh)
For the subsequent 13 years: 7.50 Rs/kWh (0.109 €/kWh)

kWh tariff with accelerated depreciation:
10.36 Rs/kWh (0.150 €/kWh)

kWh tariff with normal depreciation:
11.57 Rs/kWh (0.168 €/kWh)

- Between 1 April 2014 and 31 March 2015

MWh tariff with accelerated depreciation:
Levelised Tariff for 25 years: 8.03 Rs/kWh (0.117 €/kWh)
For the first 12 years 8.35 Rs/kWh (0.121 €/kWh)
For the subsequent 13 years: 7.00 Rs/kWh (0.102 €/kWh)

MWh tariff with normal depreciation:
Levelised Tariff for 25 years: 8.97 Rs/kWh (0.130 €/kWh)
For the first 12 years 9.42 Rs/kWh (0.137 €/kWh)
For the subsequent 13 years: 7.50 Rs/kWh (0.109 €/kWh)

kWh tariff with accelerated depreciation:
9.63 Rs/kWh (0.140 €/kWh)

kWh tariff with normal depreciation:
10.76 Rs/kWh (0.156 €/kWh)

Under the Gujarat Solar Policy, 690 MW of PV projects were connected at the beginning of September 2012 and a further 279 MW are still under development.

5.1.4 Rajasthan Solar Energy Policy

In April 2011, the State Government of Rajasthan passed its *Solar Energy Policy 2011* with the objective to develop Rajasthan into a global hub for solar power, and install a capacity of 10 to 12 GW over the next 10-12 years to meet energy requirements of Rajasthan and India. The State advertises to promote Solar Power Producers to set up Solar Power Plants along with Solar PV manufacturing plants in Rajasthan. The target is the establishment of 500 MW per annum of SPV manufacturing capacity in the State. Rajasthan plans to develop Solar Parks of more than 1,000 MW capacity in identified areas of Jodhpur, Jaisalmer, Bikaner and Barmer districts, in various stages.

In March 2012, the Rajasthan Renewable Energy Corporation published a call for 50 1 MW PV plants [Raj 2012] and the Rajastan Electricity Regulatory Commission issued the order for the new feed-in tariffs on 30 May 2012 [Raj 2012a]. The tariffs for PV systems commissioned under the JNNSM and the Rajasthan Solar energy policy until 31 March 2014 were set as:

Tariff with accelerated depreciation:
8.42 Rs/kWh (0.122 €/kWh)

Tariff with normal depreciation:
9.63 Rs/kWh (0.140 €/kWh)

At the beginning of September 2012 PV systems with a cumulative capacity of 196 MW were installed in Rajasthan.

5.2 Solar Photovoltaic R&D Programme

R&D projects are supported by the Ministry of Non-Conventional Energy Sources at research organisations of the Central or State Governments, autonomous societies, universities, recognised colleges, Indian Institutes of Technology (IITs) and industries, etc., which have suitable infrastructure for undertaking R&D in solar photovoltaic technology. R&D proposals are evaluated by experts and recommended to the Ministry for approval.

R&D is supported on various aspects of solar photovoltaic technology, including development of polysilicon and other materials, development of device fabrication processes and improvements in crystalline silicon solar cell/module technology, development of thin-film solar cell technology (based on amorphous silicon films, cadmium telluride (CdTe) films and copper indium diselenide (CIS) thin-films, organic, dye-sensitised and carbon nano-tubes). MNRE is also supporting development of photovoltaic systems and components used in the manufacturing of such systems. For the 11th Plan, the Ministry has identified the so-called ***Thrust Areas* of R & D in Solar Photovoltaic Technology.**

In order to make solar cells and modules cost effective, the global R&D efforts are directed to reduce the consumption of silicon and other materials and improve the efficiency of solar cells/modules to achieve significant cost reduction. Further R&D is also undertaken on non-silicon based solar cell modules and other aspects of PV systems.

The Ministry of New and Renewable Energy Sources has been supporting R&D and technology development in solar photovoltaic technology for more than three decades. During the 11th Plan period, it is envisaged that the cost of solar photovoltaic modules can be brought down to about Rs. 120 (€2.14) per Wp.

In order to achieve this goal, the key areas of R&D and technology development have been identified. Research, design and development efforts during the 11th Plan are proposed to be focused on the development of (I) polysilicon and other materials, (II) efficient silicon solar cells, (III) thin-film materials and modules, (IV) concentrating PV systems, and (V) PV system design, with the objective of significantly reducing the ratio of capital cost to conversion efficiency. The following are the thrust areas for R&D support in solar photovoltaic technology:

1) Polysilicon Material:

- R&D for producing polysilicon with alternative methods (non triclorsilane) with a direct electricity consumption of less than 125 kWh/kg. The quality of the material should allow for cells with efficiency higher than 15%.

- Design, develop and demonstrate at a pilot plant (100 tons annual capacity).

2) Crystalline Silicon Solar Cells & Modules

- Reduction of silicon use to 3 g/Wp for monocrystalline cells by wafer thickness reduction and efficiency increase to ≥ 18%.

- Develop and produce multi-crystalline silicon ingots/wafers and produce solar cells with conversion efficiency of 17% and more in commercial production.

- R&D on alternative device structures to make crystalline silicon solar cells to demonstrate very high efficiency (22-24% on small size laboratory devices).

- Increase PV module life to 25 years and more, with total degradation within 10% of the initial rating under STC.

- Design and development of low-cost, low-weight, non-glass type PV modules with effective module life of 10 years or more, with total degradation within 10% of the initial rating under STC.

- Study and evaluate new materials for use in PV modules.

- Develop low resistance metal contact deposition materials and processes.

3) Thin-Film Modules

- R&D on different processes and device structures to make laboratory scale small area (2cm x 2cm) devices of efficiency >10% using CdTe, CIGS and silicon thin-films.

- Development of polycrystalline thin-film integrated modules (1 sq ft or more) at pilot plant scale, using different materials (CdTe, CIGS, silicon films) to achieve efficiency of >8% and life of integrated module >15 years).

4) New Materials for Solar Cells

- Investigation and characterisation of new materials to determine their suitability for fabrication of solar cells.

- Design and development of new thin-film device structures, based on dye sensitised (liquid and solid state) organic, carbon nano-tubes, quantum-dots, etc. materials. Target: laboratory scale efficiency of 5 – 10%.

5) Concentrating Solar Cells and Modules

- Design and development of concentrator solar cells (concentration ratio of 200 X and more) with module efficiency between 25 – 30% and testing of concentrating PV system in Indian conditions.

- Development of two axis tracking systems suitable for high concentration PV systems.

- Design and development of heat sinks for mounting solar cells under high concentration.

- Design and development of optical systems to achieve concentration ratio of 200 X and more, with minimum optical aberration.

- Development of silicon and GaAs-based solar cells suitable for use under high concentration (200 X or more).

6) Storage System

- Development of long-life (5,000 cycles or more) storage batteries suitable for use in PV systems / applications.

- Development and testing of new storage systems up to MW scale. It should be possible to store electricity for about 8-10 hours, with storage losses limited to about 10%.

7) Balance of System and PV Systems

- Design and development of a small capacity inverter, including charge controller, with efficiency of 90% or more, suitable for use in solar lighting systems, including LED-based lighting systems.

- Design and development of LED-based PV lighting systems for indoor and outdoor applications

- Design, development and field-testing of inverters and grid synchronising system components (peak efficiency >96% and part load @ 30% efficiency >88%,) used in residential grid interactive rooftop PV systems.

- Field-testing and performance evaluation of grid interactive rooftop residential PV systems.

8) Testing and Characterisation Facilities

- Upgrade the testing and characterisation facilities for PV materials, devices, components, modules and systems.

- Set up of testing facilities for concentrating PV systems

- Study and evaluate new material, device structures and module designs, etc.

5.3 Solar Companies

In the following chapter some of the solar companies in India are briefly described. This listing does not claim to be complete, especially due to the fact that the availability of information or data for some companies was very fragmentary.

5.3.1 Bharat Heavy Electricals
Bharat Heavy Electricals Limited (BHEL) is the largest engineering and manufacturing enterprise in the energy-related/infrastructure sector in India today. In 2009, the company increased its manufacturing capacity of silicon solar cells and modules from 3 MW to 8 MW. For 2011, a production of 2 MW solar cells is reported [Pho 2012].

5.3.2 Central Electronics
Central Electronics Limited (CEL) is a Public Sector Enterprise under the Department of Scientific and Industrial Research (DSIR), Ministry of Science and Technology, Government of India. It was established in 1974, with an objective to commercially exploit the indigenous technologies developed by National Laboratories and R&D Institutions in the country. At the end of 2010, CEL had a production capacity of 15 MW and was planning to increase it up to 25 MW in 2012. For 2011, a production of 3 MW is reported [Pho 2011].

5.3.3 Euro Multivision Ltd.
Euro Multivision Ltd. is a subsidiary of the Euro Group and started commercial solar cell production with a 40 MW capacity in 2010. According to the company, they plan to expand their capacity to 320 MW in the future. For 2011, a production of 7.5 MW was estimated [Pho 2012].

5.3.4 HHV Solar Technologies
HHV Solar Technologies is owned by the Hind High Vacuum Company Pvt. Ltd. (HHV), a manufacturer of vacuum hardware. In 2008, HHV developed a full production line for amorphous silicon solar modules and HHV Solar Technologies set up a crystalline silicon module assembly line with 40 MW and a thin-film manufacturing line of 10 MW, which started commercial production in 2010. The company has expansion plans for an additional 30 MW (Phase 2), without a specified date.

5.3.5 Indosolar
Indosolar was founded in 2008 and has its production site at Greater Noida (Uttar Pradesh). Within 18 months, the company has set up a production capacity of 160 MW for multicrystalline solar cells. The company is increasing its capacity to 360 MW in 2012. For 2011, a production of 40 MW is reported [Pho 2012].

5.3.6 KL Solar Company
KL Solar was founded in 2004 and is located in Coimbatore, Tamil Nadu and manufactures mono and polysilicon solar cells and modules. According to the company, the total installed annual production capacity for solar cells was 27 MW and 12 MW for solar modules at the end of 2011.

For 2011, a production of 25 MW is reported [Pho 2012].

5.3.7 Moser Baer

Moser Baer Photovoltaic Limited (MBPV) and PV Technologies India Limited (PVTIL) are subsidiaries of Moser Baer India Limited. They were launched between 2005 and 2007 with the primary objective of providing reliable solar power as a competitive non-subsidised source of energy.
The production capacity is given by the company with 190 MW crystalline cells, 165 MW crystalline Modules, and 50 MW thin-films with expansion plans in place. For 2011 an actual production of 50 MW is given [Pho 2012].

5.3.8 PLG Power

PLG Power is a subsidiary of the Indian PLG Group, manufacturing solar modules in Sinnar, Nasik, since 2008. Module manufacturing capacity in 2011 reached 150 MW. The company announced that it will start solar cell production with a manufacturing capacity of 60 MW in 2011 and that it is setting up a polysilicon plant with 1,500 tons of polysilicon in Gujarat in 2012, with expansion an option to 3,000 tons by 2013.
Besides the manufacturing activities of polysilicon, solar cells and modules, the company is active in developing and investing in its own PV Power plants in India and Europe.

5.3.9 Solar Semiconductor

Solar Semiconductor was incorporated in the Cayman Islands in April 2006 and has subsidiaries in the United States and India. Manufacturing plants are located in Hyderabad, India, and, according to the company, it had reached a module production capacity of 195 MW and solar cell capacity of 60 MW at the end of 2010.

5.3.10 Tata Power Solar Systems Ltd.

The company was established in 1989 as Tata BP Solar, a joint venture between the Tata Power Company and BP Solar. After the exit of BP from the solar business, it became a fully owned subsidiary of Tata Power, moved into the project business and finally changed its name on 29 August 2012. According to the company, the manufacturing capacity is 84 MW for solar cells and 125 MW for modules. For 2011, actual production is reported as 40 MW [Pho 2012].

5.3.11 Udhaya Energy Photovoltaics Pvt Ltd.

UPV Solar has been manufacturing solar cells and modules in its plant at Coimbatore since 1988. According to the company, cell and module capacity is 12 MW.

5.3.12 Websol Energy Systems Ltd.

Websol Energy Systems Ltd. (formerly Webel SL Energy Systems Ltd.) was established in 1990 and began production in 1994. Its monocrystalline solar cell and module manufacturing facilities are located at Falta Special Economic Zone, Sector II, Falta, West Bengal. According to the company, its manufacturing capacity was 60 MW at the end of 2010 and the equipment for the expansion to 90 MW is already ordered. A further expansion to 120 MW was planned for 2012. For 2011, 32 MW of solar cell production are reported [Pho 2012].

5.3.13 Bhaskar Silicon Ltd.

Bhaskar Silicon Ltd. was set up as an independent company by Environ Energy Group as a Solar Energy Solution Provider to build solar photovoltaic power plants and large industrial solar thermal plants. In 2007, the company took over the solar business units of Shell Overseas Investment in India and Sri Lanka. In 2008, the company announced that it would build and operate an integrated polysilicon, cell and wafer-processing facility in West Bengal's industrial township, Haldia, with a planned capacity of 2,500 tons of polysilicon. However, according to financial reports, the financing of the project is still not closed.

5.3.14 Lanco Solar

Lanco Solar was established in 2008 as a business division of Lanco Infratec Ltd. and is set up along the solar value chain including Project Development for Solar Power Plants within and outside India, EPC for Solar Power Plants, Solar Products & Systems and Manufacturing. The company strategy is called “Sand to Solar” and it is building a “Fully Integrated PV facility” in the state of Chhattisgarh. Phase I includes a 75 MW module production facility, which has been in operation since 2011. In addition, a production facility for 1,800 metric tons of polysilicon, as well as a 100 MW ingot and wafering plant, is currently under construction.

6. Japan

The long-term Japanese PV research and development programmes, as well as the measures for market implementation, which started in 1994, have ensured that Japan has become a leading PV nation world-wide. The principles of Japan's Energy Policy are the **3E**s:

- Security of Japanese **E**nergy Supply (Alternatives to oil)
- **E**conomic Efficiency (Market mechanisms)
- Harmony with **E**nvironment (Cutting CO_2 emissions in line with the Kyoto Targets)

6.1 Renewable Energy Policy in Japan

After the dramatic events which took place at the Fukujima Daiichi nuclear power plant in March 2011, the current energy policy, and with it the role of renewable energies and photovoltaics, is under revision. Renewable energy will definitely play a larger role in Japan, according to Government officials.

On 10 May 2011, Prime Minister Naoto Kan said at a news conference: *"The current basic energy policy envisages that over 50 % of total electricity supply will come from nuclear power, while 20 % will come from renewable power in 2030. … But that basic plan needs to be reviewed now from scratch after this big incident."*

In July 2012, a Ministry for Economy, Trade and Industry (METI) panel proposed the long-awaited plan to reform the country's power market. The plan targets to increase renewable power supply from the 2011 level of 11 % to 25 % to 35 % by 2030. The new Basic Energy Plan is still under revision by the Ministry of Economy, Trade and Industry (METI).

The decision of the Japanese Government to "take into consideration" the phase-out of nuclear power by 2040 is very vague about when and how the phase-out-out will happen. It also includes the option to restart idle reactors during this time period. Nevertheless, this statement has already increased the speed at which new renewable energy sources are approved and has increased the number of interested investors. It is also of interest that the new METI budget request for technology development and promotion of PV systems includes a *"Project to promote the introduction of renewable energy through interchange among citizens in Fukujima Prefecture"* with a budget of ¥ 2.7 billion (€ 27 million) [Ikk 2012a]. The aim of the project is to create new industries and employment in the province.

Details of the development of the Japanese legislation and activities can be found in the earlier PV Status Reports, as well as info about the history and the main differences between the Japanese and European reasons for the introduction of renewable energies.

6.2 Implementation of Photovoltaics

The Japanese Residential Implementation Programme for Photovoltaics, which ended in October 2005, was the longest running. It started with the "Monitoring Programme for Residential PV systems" from 94 to 96, followed by the "Programme for the Development of the Infrastructure for the Introduction of Residential PV Systems", which has been running since 1997. Since then, the average price for 1 kWp, in the residential sector, fell from 2 million ¥/kWp in 1994 to 470,000 ¥/kWp in 2011.

Until 2010, residential roof-top PV systems represented about 95% of the Japanese market. In 2011, due to a change in permitting, large ground-mounted systems, as well as large commercial and industrial roof-top systems, increased their market share to about 20%.

In June 2012, METI finally issued the Ministerial Ordinances for the new feed-in tariffs for renewable energy sources. The tariff for commercial installations (total generated power) larger than 10kWp is ¥ 40 per kWh (0.40 €/kWh) for 20 years and ¥ 42 per kWh (0.42 €/kWh) for residential installations (surplus power) smaller than 10 kWp for 10 years, starting from 1 July 2012 until 31 March 2013 [Ikk 2012]. These tariffs are seen as a means to jump-start the PV installations and will be adjusted in FY 3013.

The new feed-in tariff programme triggered a significant growth of the market share of non-residential and MW-scale PV system capacity. METI announced that during the first two months of the new FIT schemes, 1.03 GW of new PV have been approved, with a mix of 565 MW for MW-scale projects, 160 MW other non-residential, and 306 MW residential systems [Ikk 2012a]. For 2012 a market between 2.2 and 2.5 GW is forecasted.

6.3 NEDO PV Programme

In Japan, the Independent Governmental Entity, New Energy Development Organisation (NEDO), is responsible for the Research Programme for Renewable Energies. The current programme for photovoltaics, in the frame of Energy and Environment Technologies Development Projects, has three main pillars [NED 2007]:

- New Energy Technology Development
- Introduction and Dissemination of New
- Energy and Energy Conservation
- International Projects

One of the dominant priorities, besides the future increase in PV production, is obviously the cost reduction of solar cells and PV systems. In addition to these activities, there are programmes on future technology (in and outside NEDO), where participation of Japanese institutes, or companies, is by invitation only. For the participation of non-Japanese partners, there are "future development projects" and the NEDO Joint Research Programme, mainly dealing with non-applied research topics.

Within the **New Energy Technology Development Programme**, there are projects on photovoltaic technology specific issues, problems of grid-connected systems, as well as public solicitation. In addition to the projects listed below, a number of new initiatives were launched in FY 2010. These projects have relevance for PV and range from R&D of next generation high performance PV systems to a demonstration project on next generation smart power transmission and distribution and R&D on combined storage systems.

Field Test Projects on Photovoltaic Power Generation
FY2007 – FY2014 (Installation work to be completed in FY2010)

To further promote the introduction of PV systems, it is considered essential to install them at public facilities, residential housing complexes, and in the industrial sector, such as at factories. The potential of such installations is comparable to that of the detached home market. Medium- and large-scale PV systems are being adopted more slowly than detached home systems, even though costs have been substantially reduced and their effectiveness, as power generation devices, has been verified. Systems, employing new modules or other innovations, will be verified through joint research activities (partly covered by technology research subsidies). Operating data is being analysed, evaluated, and published with the objective of encouraging further cost reductions and system performance improvements. NEDO and joint researchers each bear 50% of the costs.

Research and Development on Innovative Solar Cells
FY2008 – FY2014 (peer review after 3rd year)

The objective of this project is to improve drastically the conversion efficiency of solar cells, using new and innovative concepts. Tokyo University and AIST Tsukuba, in collaboration with the Tokyo Institute of Technology, were selected in July 2008 as Centres of Excellence (CoE) to carry out the tasks. The following research topics were selected and are open for international collaboration:

- **Post-silicon Solar Cells for Ultra-high Efficiencies**
  (1) Super high-efficiency concentrator multi-junction solar cells;
  (2) High efficiency quantum structure tandem solar cells and their manufacturing technologies;
  (3) Ultra-high efficiency solar cells based on quantum dots and super lattice;
  (4) Ultra-high efficiency multiple junction solar cells with hybrid materials.

- **Thin-film Full Spectrum Solar Cells with low concentration ratios**
  (1) Band-gap control of nano dots/multi-exiton/band-gap engineering of strained Ge/novel Si-based and amorphous alloy thin-films/thin-film materials design;
  (2) Si-based thin-film concentrators/wide band-gap Si based thin-films/multi-cell interface junction/Chalcopyrite based thin-film concentrators on metal substrates/optical design/CdTe thin-film concentrators;
  (3) Surface plasmons/p-type TCO/full-spectrum TCO/grapheme transparent conductive film.

- **Exploring Novel Thin-film Multi-junction Solar Cells with Highly-ordered Structure**
  (1) Highly-ordered plane poly-silane/ordered nano-crystalline Si-materials/Ge-based narrow band-gap materials/heterojunction devices;
  (2) Wide band-gap chalcogenide-based materials/solar cells using novel wide band-gap material/Oxynitride-based wide band-gap materials/Oxide-based wide band-gap materials/CIGSSe-based tandem-type solar cells;
  (3) Novel concept solar cells using nano-Si, nano-carbon and single-crystalline organic semiconductors/novel concept solar cells using correlated materials/novel concept solar cells using nano-materials with controlled structure;
  (4) Mechanical stacking-techniques/highly efficient light-trapping techniques/ improved transparent conduction oxide films using preparation techniques for improved glass substrates.

The **Introduction and Dissemination of New Energy and Energy Conservation Programme consists** of various promotional and awareness campaign projects.

Project for Promoting the Local Introduction of New Energy
FY1998 – open

This project is designed to accelerate the introduction of the New Energy Facility Introduction Project and the New Energy Introduction Promotion/Dissemination Project, which are implemented by local Governments. The Facility Introduction Project subsidises local Governments for up to 50% of equipment/facility introduction costs and up to 20 million yen for dissemination.

Non-profit organisations are also eligible for support under the New Energy Facility Introduction Project if they introduce effective new energy utilisation systems at local level. To disseminate the efforts of non-profit organisations nationally, in order to accelerate the dissemination of new energy, projects can be subsidised at up to 50% of the cost.

The **International Projects** mainly focus on neighbouring Asian developing countries to promote technological development.

International Cooperative Demonstration Project Utilising Photovoltaic Power Generation Systems
FY1992 – open

The technological development necessary for the practical application and dissemination of photovoltaic power generation systems cannot be achieved without the efficient promotion of system improvements, including system reliability verification and demonstration, as well as cost reductions. NEDO conducts the International Cooperative Demonstration Project Utilising Photovoltaic Power Generation Systems with developing countries whose natural conditions and distinctive social systems are rarely seen in Japan.

Joint Call with the European Commission:
Ultra-high concentration photovoltaics (CPV), cells, modules and systems
FY 2011 – 2014

NEDO and the European Commission launched a project to develop concentrator photovoltaic cells, aiming to achieve a cell conversion efficiency of more than 45%, which is the highest efficiency in the world. This is the first joint project under the EU-Japan Energy Technology Cooperation Agreement[30].

The Japanese research team is led by Professor Masafumi Yamaguchi of the Toyota Technological Institute and includes Sharp Corporation, Daido Steel Co., Ltd., the University of Tokyo, and the National Institute of Advanced Industrial Science and Technology. The EU research group, led by Professor Antonio Luque of the Technical University of Madrid, consists of Fraunhofer Institute for Solar Energy Systems (Germany), Imperial College London (United Kingdom), the Italian National Agency for New Technologies, Energy and Sustainable Economic Development (Italy), BSQ Solar, SL. (Spain), PSE AG (Germany) and the French National Institute for Solar Energy (France).

6.4 Solar Companies

In the following chapter those market players in Japan, not yet mentioned in Chapter 3, are described briefly. This listing does not claim to be complete, especially due to the fact that the availability of information or data for some companies was very fragmentary.

6.4.1 Kaneka Solartech

Kaneka has been involved in the development of amorphous solar cells for over 25 years. Initially this was aimed at the consumer electronics market, but overall R&D, as well as business strategy, changed in 1993 when Kaneka decided to move into the power module market for residential and industrial applications.

Currently Kaneka produces a-Si and amorphous/microcrystalline silicon modules for rooftop application and built-in roofing types for the Japanese, as well as export markets. The built-in roofing types were developed for the Japanese housing market in cooperation with Quarter-House and Kubota and are either shingle type modules or larger roofing elements. In 2006, the company opened a module factory in Olomouc, Czech Republic, where the capacity was increased to 30 MW in 2008. In FY2010, the total production capacity was expanded to 150 MWp/year. In FY 2011, production was 50 MW [Rts 2012].

[30] The EU-Japan Energy Technology Cooperation Agreement is designed to strengthen cooperation in the energy field between NEDO, which promotes the development of energy-related technologies, and the EU, which is conducting research and development programmes under the EU 7th Framework Programme for Research. The Agreement was reached at ministerial level (the Minister of Economy, Trade and Industry of Japan and the EU Commissioner for Science and Research) to promote EU-Japan cooperation in the field of energy-related technologies.

6.4.2 Mitsubishi Electric

In 1974, research and development of photovoltaic modules started. In 1976, Mitsubishi Electric established its space satellite business and 1986 saw the beginning of a public and industrial systems business. One of the largest PV systems in Japan was delivered in 1993 to Miyako Island in the Okinawa Prefecture (750 kWp). With the start of the NEDO Residential Programme, Mitubishi Electric got involved in the residential PV market in 1996. The Iida factory, Nagano Prefecture, was established in 1998, where cells and modules were manufactured. Today this plant is used for cell production and the modules are manufactured in Nakatsugawa, Gifu Prefecture, and Nagaokakyo, Kyoto Prefecture. Current production capacity is 270 MW and production in 2010 was 190 MW [Rts 2012].

6.4.3 SANYO Electric Company (Panasonic Group, Japan)

Sanyo commenced R&D for a-Si solar cells in 1975. 1980 marked the beginning of Sanyo's a-Si solar cell mass productions for consumer applications. Ten years later in 1990, research on the HIT (Heterojunction with Intrinsic Thin Layer) structure was started. In 1992, Dr. Kuwano (former president of SANYO) installed the first residential PV system at his private home. Amorphous Silicon modules for power use became available from SANYO in 1993 and in 1997 the mass production of HIT solar cells started. In 2011, Sanyo had a production capacity of 570 MW and produced 495 MW solar cells [Rts 2012]. For 2012 a capacity increase to 870 MW is foreseen.

The company now has a HIT PV module production at SANYO Energy S.A. de C.V.'s Monterrey, Mexico, with 75 MW and a module manufacturing plants in Dorog, Hungary with 315 MW. At the end of 2012, the company plans to open its new cell and module manufacturing plant in Kedah State, Malaysia with a capacity of 300 MW.

6.4.4 Solar Frontier

Solar Frontier is a 100% subsidiary of Showa Shell Sekiyu K.K. In 1986, Showa Shell Sekiyuki started to import small modules for traffic signals, and started module production in Japan, cooperatively with Siemens (now Solar World). The company developed CIS solar cells and completed the construction of the first factory with 20 MW capacity in October 2006. Commercial production started in FY 2007. In August 2007, the company announced the construction of a second factory with a production capacity of 60 MW to be fully operational in 2009. In July 2008, the company announced they would open a research centre *"to strengthen research on CIS solar powered cell technology, and to start collaborative research on mass* *production technology of the solar modules with Ulvac, Inc.”*. The aim of this project was to start a new plant in 2011 with a capacity of 900 MW. The ramp-up started in February 2011 and at the end of the year overall capacity was 980 MW. In 2011, the company changed its name to Solar Frontier and production is reported with 450 MW [Rts 2012].

6.4.5 Additional Solar Cell Companies

- **Clean Venture 21:** Clean Venture 21 Corporation was founded in 2001 as a privately held solar company and develops spherical Silicon solar cells. In 2006, CV21 opened its first production facility in Kyoto. The company claims that the cells have 12% efficiency and that the costs should be only one fifth of a conventional silicon cell thanks to the significantly reduced silicon use. CV21 entered into an exclusive sale agreement with the FujiPream Corporation in December 2005. According to the RTS Corporation, the company had a production capacity of 15 MW for spherical silicon solar cells at the end of 2011 and an actual production of 1 MW [Rts 2012].

- **Fuji Electric Systems Co. Ltd.:** In 1993, Fuji Electric started its activities in amorphous thin-film technology. The company developed amorphous-silicon thin-film solar cells in the framework of a NEDO contract. The cells, which use a plastic film substrate less than 0.1mm thick, are light, inexpensive to manufacture and easily processed into large surface areas. The capacity in 2011 was 24 MW and actual production was 5 MW [Rts 2012].

- **Honda Soltec Co. Ltd.:** Honda R&D Co. Ltd. developed a CIGS thin-film module with a power output of 112W. To commercialise the product, Honda Soltec Co. Ltd. was established on 1 December 2006. Since June 2007, the company has been selling 125 W modules produced by Honda Engineering Co. Ltd. and announced that the mass production at the Kumamoto Plant, with an annual capacity of 27.5 MW, started its production in November 2007. For 2011 a production of 6 MW is reported [Rts 2012].

- **Kyosemi Corporation** was founded in 1980 and is a research and development-oriented optoelectronic company. The company developed a proprietary spherical solar cell and in 2004 registered the trademark Sphelar®.

- **Mitsubishi Heavy Industries (MHI)** started their pilot plant production in 2001, because solar energy has attracted increasing attention as an environment-friendly form of energy. In 2008, the company started the commercial production of a-Si/µ-Si and increased its production capacity to 118 MW. In 2011 MHI transferred its tandem manufacturing with 125 MW capacity to Auria Solar (Taiwan), in which MHI now holds a 30% stake. The 13 MW Nagasaki plant is used as a development and demonstration plant [Rts 2012].

6.4.6 Suntech Power Japan

Suntech Power was founded as MSK Corporation in 1967 as an import/export company for electrical parts. Already in 1981, MSK began with sales of solar cells and in 1984 opened a photovoltaic module factory in the Nagano Prefecture. In 1992, they concluded a distribution agreement with Solarex (now BP Solar) and, at the beginning of the Japanese Residential Dissemination Programme in 1994, MSK developed the roof material “Just Roof”, together with Misawa Homes, and started sales of residential PV systems.

In August 2006, Suntech Power (PRC) announced the first step of its acquisition of MSK. Suntech acquired a two-third equity interest in MSK and completed the 100% takeover in June 2008. Current module manufacturing capacity is reported as 100 MW [Rts 2012].

6.4.7 YOKASOL

After the takeover of MSK by Suntech Power, employees of MSK's Fukuoka Plant bought the plant and set it up as a new company named YOKASOL. The company manufactures mono- and polycrystalline silicon modules. Module manufacturing capacity at the end of 2011 was reported with 60 MW, with and expansion foreseen to 100 MW in 2012 [Ikk 2012].

6.4.8 Additional Silicon Producers

- **JFE Steel Corporation:** JFE Steel began to produce silicon ingots in 2001. To stabilise their supplies of feedstock, it began to investigate techniques for producing SOG silicon in-house from metallic silicon as an alternative to polysilicon. Prototypes created with 100% metallic silicon have achieved the same high conversion efficiency as conventional polysilicon units. According to RTS, the production capacity in 2011 was about 400 tons [Rts 2012].

- **Japan Solar Silicon:** JSS was established in June 2008 as a joint venture between Chisso Corporation, Nippon Mining Holdings (since 1 April 2009 – Nippon Mining & Metals) and Toho Titanium. According to RTS, the production capacity in 2011 was about 100 tons and the capacity should be ramped up to 4,500 metric tons in 2014 [Rts 2012].

- **Mitsubishi Materials Corporation** was created through the merger Mitsubishi Metal and Mitsubishi Mining & Cement in 1990. Polysilicon production is one of the activities in their Electronic Materials & Components business unit. The company has two production sites for polysilicon, one in Japan and one in the USA (Mitsubishi Polycrystalline Silicon America Corporation) and is a shareholder (12.25%) in Hemlock Semiconductor Corporation. With the expansion of the Yokkachi, Mie, Japan, polysilicon plant, by 1,000 tons in 2010, total production capacity was increased to 4,300 tons. Actual production in 2011 was estimated at 2,800 metric tons [Rts 2012].

- **M.Setek:** This is a manufacturer of semiconductor equipment and monocrystalline silicon wafers. The company has two plants in Japan (Sendai, Kouchi) and two in the PRC, Hebei Lang Fang Songgong Semiconductor Co. Ltd. (Beijing) and Hebei Ningjin Songgong Semiconductor Co. Ltd. (Ningjin). In April 2007, polysilicon production started at the Soma Factory in Fukushima Prefecture. For 2011 a production capacity of 7,000 metric tons was reported and the production estimated at 2,300 metric tons [Rts 2012]

- **OSAKA Titanium Technologies Co. Ltd.** This is a manufacturer of Titanium and Silicon. The first step of the capacity increase from 900 tons to 1,300 tons was completed in May 2007. In 2011 a production capacity of 3,600 metric tons and an actual production of 3,500 metric tons was reported [Rts 2012].

7. Peoples's Republic of China

The production of solar cells, and the announcements of planned new production capacities in the People's Republic of China, have sky-rocketed since 2001. Production rose from just 3 MW in 2001 to 1070 MW in 2007, and for 2011 the estimates varied between 19 and 22 GW. In 2011, production capacity was increased to over 40 GW and the announcements for 2012 would add another 25% to over 50 GW. In parallel, China is ramping up its own polysilicon production capacity and tightening the regulations on new entrants for the polysilicon production.

Back in January 2011, the Chinese Ministry of Industry and Information Technology tightened the rules for polysilicon factories. New factories must be able to produce more than 3,000 metric tons of polysilicon a year and meet certain efficiency, environmental and financing standards. The maximum electricity use is 80 kWh/kg of polysilicon produced a year, and that number will drop to 60 kWh at the end of 2011. Existing plants that consume more than 200 kWh/kg of polysilicon produced at the end of 2011 will be shut down.

Then on 24 February 2012, the Chinese Ministry of Industry and Information Technology published its industrial restructuring and upgrading plan (2011-2015) for the photovoltaic industry, which tightened the regulations further [MII 2012]. In this document the ministry outlined that by 2015 it expects only to support "backbone" enterprises, which should produce a minimum of 50,000 MT polysilicon, or 5 GW of solar cell or module production. The plan also projects a cost reduction of electricity generated with PV systems to 0.8 CNY/kWh (0.098 €/kWh) by 2015 and 0.06 CNY/kWh (0.074 €/kWh) by 2020.

In 2011, China increased its polysilicon production capacity to about 120,000 metric tons, but over half of the Chinese polysilicon manufacturers are small enterprises, and the annual production capacity is generally 1,000 – 3,000 metric tons. This fact, the increased push towards larger production facilities and the enormous price pressure, are the reasons why a significant number of Chinese manufactures have closed down their production in the first half of 2012. Because of this, China already imported 48,000 metric tons of silicon during the first seven months of 2012, 35% more than during the same period last year [Etc 2012].

7.1 PV Implementation

The biggest push for renewable energies and PV implementation came with the 12th Five-Year Plan, which was adopted on 14 March 2011, China intends to cut its carbon footprint and be more energy efficient. The targets are 17% less carbon dioxide emissions and 16% less energy consumption unit of GDP.

In August 2012, the National Energy Administration (NEA) released the new renewable energy five-year plan for 2011 to 2015 [NEA 2012]. NEA calls for renewable energy to supply 11.4% of the total energy mix by 2015. To achieve this goal, the renewable power generation capacity has to be increased to 424 GW. Hydro-power is the main source, with 290 GW including 30 GW pumped storage, followed by wind with 100 GW, solar with 21 GW and biomass with 13 GW.

The plan estimates new investments in renewable energy of CNY 1.8 trillion (€ 222 billion) between 2011 and 2015. China aims to add a total of 160 GW of new renewable energy capacity during the period 2011-15, namely 61 GW hydro, 70 GW wind, 21 GW solar (10 GW small distributed PV, 10 GW utility scale PV and 1 GW solar thermal power), and 7.5 GW biomass. For 2020, the targets have been increased as well and are now a 200 GW for wind, 50 GW for solar (27 GW small distributed PV, 20 GW utility-scale PV and 3 GW solar thermal power) and 30 GW for biomass.

The investment figures necessary are in-line with a World Bank report stating that China needs an additional investment of $64 billion (€49.2 billion) annually over the next two decades to implement an "energy-smart" growth strategy [WoB 2010]. However, the reductions in fuel costs through energy savings could largely pay for the additional investment costs according to the report. At a discount rate of 10%, the annual net present value (NPV) of the fuel cost savings from 2010 to 2030 would amount to $145 billion (€111.5 billion), which is about $70 billion (€ 53.8 billion) more than the annual NPV of the additional investment costs required.

In 2009, the Ministry of Finance (MoF), Ministry of Science and Technology (MoS&T) and the National Energy Administration (NEA) announced the "Golden Sun" Programme. For 2012, projects with a total of about 2.4 GW were approved [Hau 2012].

In July 2011, the NDRC announced a feed-in scheme with the following provisions and reserved the right to make adjustments based on factors such as investment cost changes, technology development, etc. [NDR 2011]:

- 1.15 RMB/kWh (0.142 €/kWh) for projects that (a) are approved for construction by the NDRC prior to 1 July 2011, (b) complete construction and commence production of electricity prior to 31 December 2011, and (c) have not yet been verified by the NDRC in respect of its on-grid power tariff.

- 1 RMB/kWh (0.123 €/kWh) for projects that (a) are approved for construction by the NDRC after 1 July 2011, or (b) are approved for construction by the NDRC prior to 1 July 2011 but have not yet commenced production

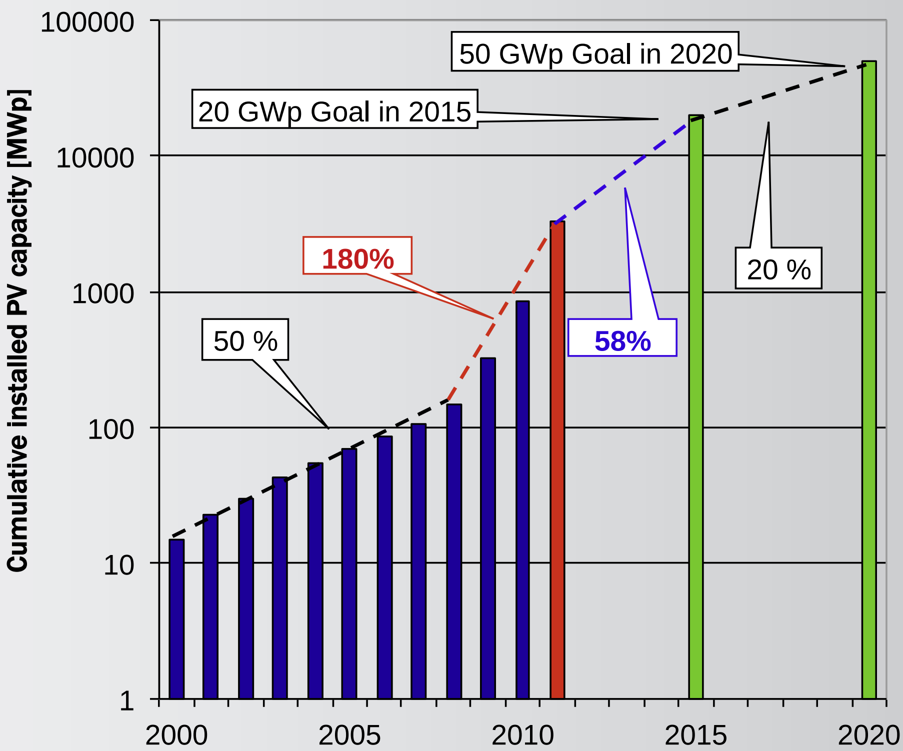


Fig. 15: Cumulative installed photovoltaic capacities in PRC, targets for 2015 and 2020 and annual growth rates.

of electricity by 31 December 2011. (Exceptions for projects of this category which are located in Tibet: 1.15 RMB/kWh (0.142 €/kWh))

Some Chinese Provinces have announced their own solar programmes, with support schemes ranging from investment subsidies, or tax incentives, for new manufacturing industries, as well as solar photovoltaic electricity plants to feed-in tariffs, which are even more favourable than the national ones.

With all these measures, the development of a multi GW size market in China is already happening and it might become the largest market from next year on. Figure 15 shows the necessary growth rates of the domestic market to realise the new targets.

7.2 Research and Development

Most of the major R&D projects are planned and conducted under the Five Year Plans. The 12th FYP (2011 to 2015) set the overall gaol to promote the scale-up of PV power generation application. Major topics are:

- Increase of PV conversion efficiencies: >20% for silicon cell, 10% for silicon-base thin-film
- Commercialise CIGS and CdTe
- Development of the design capacity and system equipment for 100 MW-class PV power station.
- Reduction of system costs to 16,000 RMB/kW (1,975 €/kW) to allow for FIT below 0.9 RMB/KWh (0.111 €/kWh)
- Reduction of actual PV power generation cost to 0.5 RMB/kWh (0.062 €/kWh)
- Establishment of national technical standards and product testing platforms.

Major technical benchmarks are listed as:

- Reduction of polysilicon production costs by 30% and at least 50% domestic supply rate of material
- Develop the ability to provide "Turn-key" silicon cell production lines with self-owned IPR and from domestic production.

The following major and key projects in PV have been arranged in the 12th FYP:

Materials

- Major project: Major technology research on high efficiency energy saving large-scale silicon materials clean production
- Key project: Research on key PV cell related materials production technology

Component area

Major projects:

- Proof of concept for new PV cells and advanced technology research
- Develop technologies for the production of low-cost ultra-thin silicon cells with efficiency >20%
- R&D on equipment and complete production processes for the production of large-scale thin-film PV cells with efficiency >10%.

Key projects:

- R&D to develop a complete Dye-sensitised Solar Cells (DSCs) production line with an annual production capacity of 5 MW with 8% module efficiency.

System area

- Major project: Demonstration of large-scale grid-tied and micro-grid PV system designs and system integration including R&D on related equipment
- Key project: Development and demonstration of silicon-based BIPV products

Also the National Medium- and Long-Term Renewable Energy Development Plan has listed solar photovoltaic power generation as an important developing point. The Chinese Environmental Protection Agency (EPA), as well as the Chinese Academy of Science (CAS), support R&D in PV industry, e.g.: EPA supports the "Study on renewable energy (Solar panel)'s impacts on environment and its manufacturing management" and CAS supports the project "Development and demonstration of power prediction of large-scale PV power station and research on large-scale PV power station's impact on local environment". Within the National Basic Research Programme of China, the so-called 973 Programme, there are additional topics like "Basic research of mass hydrogen production using solar energy" or "R&D for new concept of next generation of super-efficiency PV cells with 40% conversion efficiency".

7.3 Solar Companies

In the following chapter, some of the major market players in the PRC, not yet mentioned in Chapter 3, are described briefly. This listing is far from being complete, due to the fact that more than 150 solar-cell and more than 300 solar-module-companies exist in China. According to a market research done by ENF, more than 70 companies started solar cell manufacturing activities in China between 2010 and mid 2012. Some of them, like Hareon Power or Talesun Solar have joined the GW production capacity league. In addition, availability of information or data for some companies is very fragmentary.

7.3 1 Aiko Solar Energy Technology Co., Ltd.
Aiko Solar was founded in 2009 and is located in Foshan City, Guangdong Province. Commercial solar cell production started in June 2010, with a 120 MW capacity and the expansion to 240 MW was completed in March 2011. According to the company, a further expansion to 1 GW is ongoing. The company took over the solar cell and module business of Scheuten Solar in Germany in 2012. For 2012, a production of 350 MW is reported [Pho 2012].

7.3.2 Astronergy Solar
Astronergy Solar was established as a member of the Chint Group in October 2006. The first production line of 25 MW, for crystalline silicon cells and modules, was installed in May 2007 and an increase of the production capacity to 100 MW was finished in July 2008. Commercial production of micromorph® solar modules started in July 2009. The thin-film capacity was 30 MW in 2010 and the company planned to increase it to 75 MW early 2011. Total production capacity for 2011 is reported with 750 MW and 514 MW of production [Pho 2012].

7.3.3 BYD Solar
BYD (Build Your Dream) Company Ltd. was established in February 1995 and specialises in IT, automobile and new energy. The company's green energy division provides solar modules (ranging from BYD wafer to PV module assembly), inverters, Li-ion batteries and LED lighting. The company started its solar manufacturing activities in 2008. According to company representatives, the company now has a production capacity of 750 MW and plans to increase it to 5 GW by 2016.

7.3.4 CETC Solar Energy Holdings Co., Ltd.
CETC Solar Energy Holdings Co., Ltd. is a technology company providing solar energy manufacturing equipment, solar cells and modules, together with solar power solutions, all based upon a common technology platform. It consists of a group of institutes and companies, namely, the 48th Institute of China Electronics Technology Group Corporation (CETC), Beijing Zhongkexin Electronics Equipment Co., Ltd., Hunan Red Solar New Energy Science and Technology Co., Ltd., and Hunan Red Solar Photoelectricity Science and Technology Co., Ltd. According to the company, it is operating 60 solar cell lines with a combined capacity of 1.5 GW.

7.3.5 China Sunergy
China Sunergy was established as CEEG Nanjing PV-Tech Co. (NJPV), a joint venture between the Chinese Electrical Equipment Group in Jiangsu and the Australian Photovoltaic Research Centre in 2004. China Sunergy went public in May 2007. At the end of 2008, the Company had five selective emitter (SE) cell lines, four HP lines, three capable of using multicrystalline and monocrystalline wafers, and one normal P-type line for multicrystalline cells, with a total nameplate capacity of 320 MW. At the end of 2011, the company had a cell capacity of 404 MW and a module capacity of 915 MW. For 2012, a capacity increase to 750 MW cells and 1.15 GW of modules is foreseen. For 2011, shipments of about 420 MW were reported.

7.3.6 CSG PVTech Co. Ltd.
CSG Solar is a part of the CSG Holding Co. Ltd., which was founded in Shenzhen Economic Special Zone in 1984. CSG has become a leading manufacturer of architectural energy-saving glass. CSG Solar was set up in 2006 and commercial silicon solar cell and module production began in 2008. CSG works along the PV value chain covering poly-silicon, ingot, wafer, solar cell, solar glass and solar modules. In 2010, a 75 MW thin-film plant went into operation in Dongguang. Wafer, solar cell and module capacity expansions are planned, and according to the company, the manufacturing capacity should reach 350 MW each by 2013. Production in 2011 was reported with 100 MW [Pho 2012].

7.3.7 DMEGC Solar Energy
DMEGC Solar Energy is a Division of the Hengdian Group DMEGC Magnetics Co., Ltd. (DMEGC). DEMEGC Solar started in 2009 and has now seven production sites manufacturing ingots/rods, wafers, solar cells and solar modules. It is headquartered in Hengdian, Dongyang, with over 3000 employees. According to the company, they have a capacity of more than 300 MW for solar wafers (Henan) and modules (Hengdian & Dongyan), as well as 1 GW of solar cells (Hengdian). DMEGC has also launched a project to manufacture polysilicon. The first phase of the project, with an annual capacity of 6,000 tons, was planned to become operational at the beginning of 2012. For 2011 a production of 215 MW is reported [Pho 2012].

7.3.8 Hanergy Holdings Group Ltd.

Hanergy, founded in 1994, is China's largest privately held energy enterprise with assets in hydroelectricity, wind electricity and solar electricity generation and other energy related services. Hanergy is heavily investing in solar photovoltaics (PV) research and manufacturing facilities in seven Chinese provinces: Sichuan, Guangdong, Hainan, Zhejiang, Shandong, Heilongjiang and Jiangsu. According to the company, it plans to have 3 GW production capacity by the end of 2012. Hanergy launched its first products in 2011 and in 2012 acquired the CIGS manufacturer Solibro (Germany) and MiaSole (USA).

7.3.9 Jetion Holdings Ltd.

The group was founded in December 2004, went public in 2007, and manufactures solar cells and modules. For 2011, a production capacity of 900 MW and actual production of 500 MW is reported [Pho 2012].

7.3.10 Jiangxi Risun Solar Energy Co., Ltd.

Risun Solar Technologies was established in 2008. The company manufactures mono- and multicrystalline solar cells and modules. According to the company, the production capacity is 700 MW for solar cells and 300 MW for modules. An expansion to 3 GW is planned without a specified date. For 2011 a production of 500 MW is reported [Pho 2012].

7.3.11 Magi Solar Energy Technology

In June 2010, Dongfang Electric Corporation (DEC), a maker of heavy electrical equipment, signed an agreement to restructure Magi Solar Energy Technology. At that time, Magi Solar had an annual capacity of 180 MW and increased it to 480 MW in 2011. For 2011, a production of 200 MW is reported [Pho 2012].

7.3.12 Shanghai Topsolar Green Energy Ltd.

Topsolar is a joint-stock company, established by Shanghai Electric Group Holding Co., Ltd., Shanghai Jiao Da NanYang Co., Ltd., and Shanghai Zhenglong Technology Investment Co., Ltd. The company manufactures mono- and multicrystalline solar cells and modules. For 2011, a production capacity of 10 MW and a production of 80 MW is reported [Pho 2012].

7.3.13 Shenzhen Topray Solar Co.,Ltd.

The company was founded in 1992 and manufactures solar cells, solar chargers, solar lights, solar garden products and solar power systems, as well as solar charge controllers, solar fountain pumps and solar fan caps. From the beginning, the company manufactured thin-film solar cells and added mono- and multicrystalline cell production in 2004. The company went public in 2011. For 2011, a production capacity of 400 MW and an actual production of 85 MW is reported [Pho 2012].

7.3.14 Sungen International Ltd.

Sungen is a division of the Hong Kong based Anwell Group and was founded in 2008. The company manufactures amorphous silicon solar cells and modules in Hennan and mono- and multicrystalline modules in Suzhou. According to the company, the current capacity for amorphous silicon modules was 150 MW in 2011.

7.3.15 Sun Earth Solar Power Co. Ltd.

Sun Earth Solar Power, or NbSolar, has been part of China's PuTian Group since 2003. The company has four main facilities for silicon production, ingot manufacturing, system integration and solar system production. According to company information, Sun Earth has imported solar cell and module producing and assembling lines from America and Japan.

In 2007, Sun Earth Solar Power relocated to the Ningbo high-tech zone, with the global headquarters of Sun Earth Solar Power. There the company produces wafers, solar cells and solar modules. In 2011 the company had a production capacity of 250 MW of solar cells and 600 MW modules. For 2011, shipments of 450 MW were reported [Pho 2012].

7.3.16 Talsun Solar Co. Ltd.

Zhongli Talesun is a wholly owned subsidiary of Zhongli SCI-Tech and is listed on the Shenzhen Stock Exchange. It was set up in 2011. The company manufactures solar cells and modules and also develops solar projects. According to the company it has a 3GW cell and module capacity in 2012.

7.3.17 Trony Solar Holdings Company, Ltd.

Trony Solar is located in Shenzhen, Guangdong Province, and manufactures thin-film silicon solar cells and modules for BIPV and consumer applications. According to the company, the capacity was 205 MW at the end of 2010. In January 2012, the company reported an increase of their module capacity to 265 MW. For 2011, a production of 146 MW is reported [Pvn 2012].

7.3.18 Zhejiang Sunflower Light Energy Science & Technology Co., Ltd.

Sunflower was funded by Hong Kong YauChong International Investment Group Co., Ltd., founded in 2004 in Shaoxing, Zhejiang and went public in 2010. According to the company, current capacity is 400 MW. For 2011, a production of 200 MW is reported [Pho 2012].

7.3.19 Additional Solar Cell Companies

- **Aide Solar** is based in the Economic Development Zone of Xuzhou and was founded in 2003. In 2007, it became a subsidiary of the Taiwanese Panjit Group. According to the company, it has a solar module capacity of 700 MW and a solar cell capacity of 300 MW. In January 2011, the company announced that it started to increase its production capacity to 2 GW without a date set.

- **Amplesun Solar**, located in the Xiasha Export Processing Zone, is a private company, founded in early 2008. According to the company, it currently has an annual capacity of over 25 MW, with its first amorphous silicon thin-film production line which was supplied by ULVAC, Japan. For 2011, a production of 22 MW is reported [Pho 2012].

- **Best Solar Hi-Tech Co., Ltd.** was set up by LDK Solar's founder and CEO Xiaofeng Peng and started operations in February 2008. The company aims to produce amorphous/microcrystalline silicon thin-film modules and has contracted AMAT for the equipment. The ground-breaking for their "Site 1" in JinagSu SuZhou took place in February 2008 and for "Site 2" in JiangXi NanChang in June 2008. In November 2009, phase one with 130 MW production capacity started the ramp up. Production capacity and production is reported with 120 MW and 28 MW respectively [Pho 2012].

- **ENN Solar Energy** (part of XinAo Group) was set up in the Langfang Economic and Technological Development Zone in 2007. In November 2007, ENN Solar Energy signed a contract with AMAT for a SunFab thin-film production line to produce ultra-large 5.7 m^2 (GEN 8.5) solar modules. The 50 MW line is planned to be the first phase of an expected 500 MW capacity plant. Commercial production started in 2009. Production capacity and production is reported with 65 MW and 30 MW respectively [Pho 2012].

- **Nantong Qiangsheng Photovoltaic Technology Co., Ltd.** (QS Solar, Shanghai, China) started the production of amorphous silicon thin-film solar with their new 25 MW production line in January 2008. The company announced that it would add two more production lines in 2008, bringing the total production capacity to 75 MW. In 2011 a production capacity of 165 MW and an actual production of 65 MW is reported [Pho 2012]

- **Solargiga Energy Holdings Ltd.** was incorporated in March 2007 and listed on the Hong Kong Stock Exchange on 31 March 2008. The Group operates polysilicon reclaiming and upgrading facilities in Shanghai and Jinzhou. According to the company, it has an ingot production capacity of 1.2 GW, a wafer production capacity of 900 MW, a solar cell production capacity of 300 MW and a module production capacity of 150 MW in 2012. The company reported shipments of 139 MW of solar cells and about 100 MW of modules, including own power projects.

- **Yunnan Tianda Photovoltaic Co. Ltd.** is one of the oldest companies which make, design, sell and install solar modules and PV systems in China and was founded in 1977 as the Yunnan Semi-Conductor Device Factory. In 2005, the production capacity of solar cells was extended to 35 MW and the production of 5-inch solar cells started. In 2006, the capacity was increased to 60 MW and in 2007 the production capacity of solar cells was extended to 100 MW. In 2011, a production of 70 MW was reported [Pho 2012]

Due to the new industrial restructuring and upgrading plan published by the Chinese Ministry of Industry and Information Technology in February 2012, the whole structure of the polysilicon manufacturing industry, including the wafer manufacturers, already changed or is in the process of rapid change. Therefore, the Status Report does not cover this segment this year.

In addition, there are a considerable number of additional companies along the whole value chain. However, information is still very fragmented and due to the rapid development quickly goes out of date. In the meantime, an increasing number of consultancies are providing market analysis and study tours. The PRC's Long-Term Energy Plan calls for a considerable strengthening of the solar industry and all aspects from silicon production, wafering, cell and module manufacturing and distribution, are covered.

Chinese manufacturers are expected to export their products as Chinese PV production will grow much faster than the market. Very different from Europe or the USA, photovoltaics in China is discussed at the level of a strategic industry policy for the future.

8. South Korea

In 2008, the South Korean Government announced the "Low Carbon, Green Growth" Plan and in 2010, it announced the intention to invest KRW 40 trillion (€ 26.3 billion[31]) by 2015 in renewable energy in order to increase its competitiveness in the sector and join the world's top five countries in the sector. This "green growth" strategy is aimed at turning environmental technologies into the main drivers of economic growth and new sources of jobs. Under the Plan, the Government will work together with the private sector to invest about half of the amount KRW 20 trillion (€13.2 billion) in solar power. The PV industries are seen as the 'next semiconductor' industries and the Government policy is aimed to make them the back-bones of the future national economy. This makes clear that the Korean Government's support towards the PV industry is an industry policy and is aimed to increase Korean exports!

8.1 Implementation of PV

In January 2009, the Korean Government announced the Third National Renewable Energy Plan, under which renewable energy sources should steadily increase their share of the energy mix between 2009 and 2030. The Plan covered areas like investment, infrastructure, technology development and programmes to promote renewable energy. The Plan called for a Renewable Energies share of 4.3% in 2015, 6.1% in 2020 and 11% in 2030.

Since January 2012, Korea's Renewable Portfolio Standard (RPS) officially replaced the feed-in tariffs. For 2012, a solar installation RPS target of 220 MW was set, which is well below the actual installed capacity and the gradual increases to 1.2 GW in 2015. The average spot market value of the Renewable Energy Certificates (RECs) for solar was about 165,000 KRW/MWh (116.5 €/MWh[32]). Depending on the type of solar installation, the RECs are then multiplied by a REC multiplier, varying between 0.7 for ground-mounted free-field systems to 1.5 for building-adapted systems.

The new Renewable Portfolio Standard (RPS) Programme obliges power companies, with at least 500 MW of power capacity, to increase their renewable energy mix from at least 2% in 2012 to 10% by 2022. The renewable energy mix in the Korean RPS is defined as the proportion of renewable electricity generation to the total non-renewable electricity generation.

[31] Exchange rate: 1 € = 1,520 KRW
[32] Exchange rate: 1 € = 1,420 KRW

The total installed power of PV electricity systems in Korea increased to 812 MW at the end of 2011 [IEA 2012b]. The new annual installed power in 2011 has increased to 156 MW, about 20% more than the 131 MW installed in 2010. 77% of the total cumulative installed power are grid-connected centralised systems, whereas only 22% are grid-connected distributed systems.

8.2 Solar Companies

In the following chapter those market players in Korea, not yet mentioned in Chapter 3, are described briefly. This listing does not claim to be complete, especially due to the fact that the availability of information or data for some companies was very fragmentary.

8.2.1 GETWATT

GETWATT is the Energy Division of KISCO and launched its PV business in 2008. The company runs an a-Si manufacturing line with 20 MW capacity. Production for 2011 is reported with 15 MW [Pho 2012].

8.2.2 Hankook Silicon Co. Ltd.

Hankook Silicon was established in 2008 and its polysilicon plant is located in Yeosu, Jeollanam-do. According to the company, commercial production started in 2010 and the nameplate capacity of 3,200 tons was reached in April 2011. The company plans to increase its production capacity to 14,500 tons by 2013.

8.2.3 Hyundai Heavy Industries

In 2005, Hyundai Heavy Industries established their Renewable Energy Department, dealing with solar and wind power. The solar cell factory is located in Eumesong, Chungcheongbuk-do, and reached a production capacity of 600 MW at the end of 2011 and expansion is planned to 1 GW in 2012 and 2 GW in 2013. For 2011 a production of 400 MW is reported [Pho 2012].

8.2.4 JUSUNG Engineering

JUSUNG Engineering is a semiconductor and solar cell equipment manufacturer founded in 1995. The company developed and produces manufacturing equipment for thin-film solar cells, as well as crystalline silicon solar cells.

8.2.5 Kyungdong Photovoltaic Energy (KPE) Co. Ltd.

KPE Solar was established as Photon Semiconductor & Energy (PSE) in 2000 and started solar cell production in 2003 with a 6 MW line. In 2006, PSE merged with the plant division of Kyungdong Construction Co. Ltd. and changed the name to Kyungdong Photovoltaic Energy. At the end of 2011, the company had a production capacity of 100 MW and 50 MW of production was reported for 2011 [Pho 2012].

8.2.6 LG Solar

GoldStar was founded in 1958 and in 1995 became LG. Already in 1985, GoldStar Electronics conducted research on polycrystalline solar cells. In 2004, the LG business group consolidated several solar research laboratories under the LG Electronics umbrella, using decades of R&D experiences. In 2009, LG Electronics built a PV cell and module factory in Gumi, with a capacity of 120 MW. The company announced that it would increase its production capacity to 330 MW in 2011 and 1 GW in 2013. Production in 2011 was reported as 150 MW [Pho 2012].

8.2.8 Millinet Solar Co. Ltd.

Millinet Solar was established in 2005 and started multi-crystalline solar production in 2007. Since then, the production capacity has increased to 100 MW at the end of 2010 and the company was aiming to reach 1 GW by 2013. According to media reports, the company shut down operations at the end of last year. Production for 2011 is reported with 30 MW [Pho 2012].

8.2.9 Samsung Solar Energy

In 1987, Samsung started its R&D Programme on Buried Contacts, PERL, SP technologies, and thin-film technologies. In 2009, the company set up a 35 MW silicon pilot line in Giheung-gu, Yongin-si, Gyeonggi-do, and in May 2010, the company announced the intention to invest KRW 6 trillion (€ 3.85 billion in its photovoltaics business) to reach a production capacity in the GW range by 2020. Production in 2011 was estimated at 50 MW [Pho 2012].

8.2.10 Shinsung Solar Energy Co.

Shinsung Solar Energy started as Shinsung ENG in 1977 and moved into the solar cell business in 2007. Since then the production capacity was increased to 350 MW in 2011. According to the company, the production capacity should be increased to 600 MW by 2015. Production for 2011 was reported with 350 MW [Pho 2011].

8.2.11 STX Solar

STX Solar was established in 2007 as a subsidiary of the STX Corporation, formerly from Ssangyong Heavy Industries. The company started its commercial solar cell production with a 50 MW plant in 2009 and increased the capacity to 180 MW in 2011.

9. Taiwan

Since 2010, Taiwan has been the second largest producer of solar cells after the People's Republic of China. Unlike the PRC, the main focus is still on export, and the home market is developing very slowly.

As an emerging industrial nation, Taiwan, in its recent past, has focused towards an industrial structure, with emphasis on the manufacturing industry, which resulted in a relatively high energy consumption and greenhouse gas emissions. Over the last 15 years, Taiwan's energy consumption has almost doubled from 2.55 EJ in 1993 to 4.99 EJ in 2007, and then slightly decreased to 4.69 EJ in 2009 and back to 4.93 EJ in 2010. This, and the fact that Taiwan's current energy supply is still dominated by imported traditional fossil energy sources with almost 90% (2010: crude oil and petrol products 40.3%, coal and coal products 37.9%, natural gas 10%), makes the country highly vulnerable to price volatility and supply disruptions. In order to enhance security of supply, there is a need to diversify the energy supply, as well as the need to move to less carbon-rich energy sources to reduce greenhouse gas emissions.

9.1 Policies to promote Solar Energy

In 2002, the *Renewable Energy Development Plan* was approved by the Executive Yuan and aimed for 10% or more of Taiwan's total electricity generation capacity by 2010. Depending how Renewable Energy is accounted for (with or without municipal waste), the share of the renewable electricity generation capacity at the end of 2010 was around 5.8 to 8.3% and delivered about 2% of the total electricity consumption.

In 2004, Taiwan enacted *"Measures for Subsidising Photovoltaic Demonstration Systems"*, as part of its National Development Plan by 2008. The Solar Energy Development Project has a number of long-term goals. The plans envisage that a total of 7.5 million residents should utilise solar energy by 2030. Industrial and commercial use should be about half that of residential use. Public utilities are expected to have the same solar power generating capacity as the industrial and commercial sectors, and independent solar power generating systems will be set up in mountain areas and on off-shore islands. The aim is that in 2020, the island's renewable power capacity should reach 6.5 GW (1.2 GW PV).

In July 2008, the Cabinet in Taiwan decided to designate solar energy and light emitting diodes (LED) as two industries to actively develop in the near future. The Government encouraged households to install solar panels to generate power and to replace existing public lighting with LED lamps to save electricity.

It is estimated that the two above industries may generate production value exceeding NT$1 trillion (€24.4 billion)[33] by 2015. To promote the solar energy industry, the Government subsidises manufacturers engaging in R&D and offers incentives to consumers that use solar energy. With the help of official programmes, material suppliers are expanding operations and increasing their investments in the field. In addition, about a dozen manufacturers expressed the intention to invest in fabricating thin-films for solar cells and eight of them will set up their own plants to process the products. The solar energy industry may see its output reach NT$ 450 billion (€10.98 billion) by 2015.

The Industrial Technology Research Institute (ITRI), a Government-backed research organisation, has drawn up an R&D Strategy for Taiwan, with the aim to lower module costs to around 1 $/Wp between 2015 and 2020. The research topics identified range from efficiency increase in the various wafer-based and thin-film solar cells to concentrator concepts and novel devices. Despite the fact that the national R&D budget should be doubled within the next four years, it is visible that the main focus is on the industry support to increase production capacities and improve manufacturing technologies.

In 2008, the Ministry of Economic Affairs (MoEA) published the guidelines of Taiwan's Sustainable Energy Policy [GoT 2008]. The declared policy objective is to create a *Win-Win-Win Solution for Energy, the Environment and the Economy.* To achieve this, sustainable energy policies should support the efficient use of the limited energy resources, the development of clean energy, and the security of energy supply. The following targets were defined:

1. Improvement of energy efficiency:
The goal is to improve energy efficiency by more than 2% per annum, so that when compared with the level in 2005, energy intensity will decrease 20% by 2015. Supplemented by further technological breakthroughs and proper administrative measures, energy intensity will decrease 50% by 2025.

2. Development of clean energy:
(1) Reduce nationwide CO_2 emission, so that total emission could return to its 2008 level between 2016 – 2020, and be further reduced to the 2000 level in 2025.
(2) Increase the share of low carbon energy in electricity generation systems from the current 40% to 55% in 2025.

3. Securing stable energy supply:
Build a secure energy supply system to meet economic development-goals, such as 6% annual economic growth rate from 2008 to 2012, and 30,000 $ per capita income by 2015.

On 12 June 2009, the Legislative Yuan gave its final approval to the Renewable Energy Development Act (REDA) to bolster the development of Taiwan's green energy industry. The new law authorises the Government to enhance incentives for the development of renewable energy via a variety of methods, including the acquisition mechanism, incentives for demonstration projects and the loosening of regulatory restrictions. The goal is to increase Taiwan's renewable energy generation capacity by 6.5 GW to a total of 10 GW within 20 years.

In December 2009, the Ministry of Economic Affairs (MoEA) set the feed-in tariffs, which will be paid for 20 years. For systems between 1 and 10 KW, customers were able to opt for a higher tariff, or a lower tariff, if they opted for an additional investment subsidy of 50,000 NT$/kW (1,220 €/kW). The tariffs were set between 11.12 NT$/kWh (0.2712 €/kWh) and 4.60 NT$/kWh (0.3561 €/kWh) depending on the size and type of the PV system.

Following the general price reductions of PV electricity generation stems, the feed-in tariffs were lowered at the beginning of 2011 by approximately 30%, and again on 1 January 2012 (5.8 to 8.3% reduction) and 1 July 2012 (7.8 to 10.3% reduction). For 2013. the tariffs were set with reduction rates between 9.23 and 12.63% for the first half and 1.9 to 5.62% for the second half of the year.

The tariffs in the second half of 2012 were:

- Rooftop System size 1 to 10 kW:
  9.251 NT$/kWh (0.237 €/kWh[34])
- Rooftop System size 10 to 100 kW:
  8.326 NT$/kWh (0.213 €/kWh)
- Rooftop System size 100 to 500 kW:
  7.970 NT$/kWh (0.204 €/kWh)
- Rooftop System size > 500 kW:
  7.187 NT$/kWh (0.184 €/kWh)
- Ground mounted systems
  6.760 NT$/kWh (0.173 €/kWh)

According to EPIA, a total of about 70 MW of PV systems were cumulative installed in Taiwan at the end of 2011.

[33] Exchange Rate 2008: 1 € = 41 NTD

[34] Exchange rate 2012: 1 € = 39 NT$

9.2 Solar Companies

In the following chapter, some of the Taiwanese market players, not yet mentioned in Chapter 3, are briefly described. This listing does not claim to be complete, especially due to the fact that the availability of information or data for some companies was fragmentary.

9.2.1 Auria Solar Co.

Auria was founded in October 2007 as a joint venture between E-Ton Solar, Lite-On Technology Corp, Hermes-Epitek Corp. and the MiTAC-SYNNEX Group to manufacture thin-film solar cells. The company has chosen Oerlikon as equipment supplier and plans to produce amorphous/micromorph silicon thin-films. The first factory, with a capacity of 60 MW, began pilot production at the end of 2008 and ramped up to full capacity in 2019. In March 2011, the company announced a cooperation agreement with Mitsubishi Heavy Industries (Japan) and the 125 MW line from MHI was installed at the end of 2011. For 2011, a production of 45 MW is reported [Pho 2012].

9.2.2 Big Sun Energy Technology Incorporation

Big Sun was founded in 2006, and started its solar cell production in the third quarter of 2007 with a capacity of 30 MW. According to the company, the production capacity in 2011 was 150 MW and further expansion to 270 MW is foreseen. Production in 2011 is reported with 105 MW [Pho 2012].

9.2.3 DelSolar Co. Ltd.

DelSolar was established as a subsidiary of Delta Electronics in 2004 and went public in November 2007. In May 2012, it was listed on the Taiwan Stock Exchange's (TWSE) main board and reported a production capacity of 600 MW (440 MW PRC, 160 MW Taiwan). DelSolar has a strategic cooperation with the Industrial Technology Research Institute (ITRI). For 2011, a production of 386 MW is reported [Pho 2012].

Together with IBM, Tokyo Ohka Kogyo Co. Ltd. (TOK) and Solar Frontier DelSolar, developed its CZTS thin-film solar cell technology with lab efficiency of 10%.

9.2.4 E-TON Solartech Co. Ltd. (Taiwan)

E-Ton Solartech was founded in 2001 by the E-Ton Group; a multinational conglomerate dedicated to producing sustainable technology and energy solutions and was listed on the Taiwan OTC stock exchange in 2006.

At the end of 2011, the production capacity was 560 MW per annum and a production of 200 MW was reported [Pho 2012].

9.2.5 Mosel Vitelic Inc.

The Group's principal activities are the design, research, development, manufacturing and sale of integrated circuits and related spare parts. As part of a five-year transformation project, the company moved into the solar cell business in 2006. According to the company, it plans to develop thin-film solar cell production from its own technology and to expand production capacity to 1.5 GW by 2014. For 2011, a production capacity of 150 MW and a production of 70 MW is reported [Pho 2012].

9.2.6 Nexpower Technology Corporation

Nexpower was formed by United Microelectronics Corporation (UMC) in 2005. UMC is one of the world-wide IC foundry providers. In addition to crystalline silicon solar cells, Nexpower is dedicated to silicon thin-film photovoltaics technology and commercial applications, by building up a new manufacturing facility in Hsin Chu, Taiwan, with an annual production capacity of 25 MW in 2008. According to the company, they have a production capacity of 100 MW and production in 2011 was reported as 100 MW [Pho 2012].

9.2.7 Solartech Energy Corp.

Solartech was founded in June 2005. Solartech expanded its production capacity from 60 MW to 500 MW in 2010. According to the company, it currently has a production capacity of 800 MW and plans to expand it to 1.6 GW, without a date set. For 2011, a production of 440 MW is reported [Pho 2012].

9.2.8 Sunrise Global Solar Energy

Sunrise is located in Yilan and started commercial production for silicon solar cells, with an initial manufacturing capacity of 40 MW in 2009. In 2010, Sino-American Silicon Products (SAS), became the largest shareholder and the company announced their expansion plan to reach 320 MW by 2011. For 2011, a production capacity of 350 MW and a production of 120 MW is reported [Pho 2012].

9.2.9 Tainergy Tech Company Ltd.

Tainergy was founded in 2007 and went public in March 2010. According to the company, production capacity was 60 MW in 2008 and they increased it to 240 MW in 2010. The company announced plans to build a factory in Eastern China with a total capacity of 800 MW. According to the company, its current production capacity is 500 MW in Taiwan and phase 1 of the Kunshan, China, expansion with a capacity of 60 MW was opened in October 2011. For 2011, a production of 150 MW is reported [Pho 2012].

9.2.10 Taiwan Solar Energy Corporation

TSEC was established in June 2010 and plans to have a production capacity of 1.5 GW solar cells and modules by 2014. According to the company, it had a production capacity of 500 MW by the end of 2011. For 2011, a production of 80 MW is estimated [Pho 2012].

9.2.11 Topcell Solar International Inc.

Topcell Solar International (TSI) was founded in December 2009 by United Microelectronics Corporation (UMC). Production started in 2010 with a capacity of 150 MW, which was increased to 630 MW in 2011. According to the company, a further expansion to 1 GW is planned. For 2011, a production of 350 MW is reported [Enf 2012].

9.2.12 Additional Taiwanese Companies

AUO Solar was established as a Business Unit of AU Optronics Corporation (AUO), a global player of thin-film transistor liquid crystal display panels (TFT-LCD), in 2009. The company acquired the Japanese polysilicon manufacturer, M. Setec, in 2009. AUO established a solar module plant in Brno, Czech Republic, with a nameplate capacity of 100 MW. In July 2010, AUO entered into a joint venture agreement with SunPower to invest in a solar-cell manufacturing facility in Malaysia. Following this collaboration in technology and intellectual property, AUO achieved the mass production of solar cells with a record-breaking conversion efficiency rate of 22.5%. The aim for 2013 is a 1.4 GW annual supply. In February 2011, the company announced that their subsidiary, AUO Crystal Corp. ("ACC"), will establish a solar wafer plant in Taiwan's Chungkang Export Processing Zone.

- **AxunTech Solar Energy** was established in 2007 to fabricate CIGS solar modules. In 2010, the company started commercial production of CIGS solar modules, with a production capacity of 25 MW. According to the company, the capacity will be increased to 100 MW in 2012 and 1 GW in 2015.

- **BeyondPV Co., Ltd,'s** main shareholder is optical film maker Efun Technology and produces amorphous/microcrystalline silicon thin-film modules. The company had an annual capacity of 40 MWp in 2010, and plans to expand to 80 MWp by 2011, and 350 MWp by 2014. However, no updated information could be found in 2012.

- **Ever Energy Co., Ltd.** was established in October 2005 by a group of investors. In early 2007, Ever Energy signed a contract with Centrotherm AG, Germany, to purchase equipment with 90 MW capacity for the initial phase of a 210 MW facility. In 2011, it adopted the DNA technology patented by Day4 and signed a license agreement.

- **Green Energy Technology (GET)** was founded as a subsidiary of the Tatung Group of companies in Taiwan and went public in 2008. GET's initial capacity in May 2005 was 25 – 30 MW wafers with 13 furnaces, band saws, and wire saws. At the end of 2010, the company reported an ingot growing capacity of 1.14 GW and a wafer slicing capacity of 960 MW. According to the company, it is planned to increase the wafer and cell capacity above 1.5 GW. The company purchased a fully-integrated thin-film solar cell production line with a nominal rated capacity of 50 MW from Applied Materials and started mass production in December 2008. Capacity for 2011 is given with 45 MW and a production of 2 MW is reported [Pho 2012].

- **Jenn Feng Co., Ltd.** was incorporated in 1975. The company plans and installs solar systems. According to the company, commercial production on their first CIGS 30 MW line started in December 2009. For 2011, a production capacity of 60 MW and a production of 25 MW is estimated [Enf 2012].

- **Kenmos Photovoltaic** was founded as a joint venture of Kenmos Technology Co., Ltd., NanoPV Corporation and a Taiwanese equipment manufacturer in September 2007. Kenmos PV set up a 10 MW amorphous silicon thin-film production capacity and started mass production in February 2009. According to the company, they plan to expand their production capacity to 500 MW before 2015.

- **Sunner Solar Corporation** was founded in Taoyuan, Taiwan, in June 2007. The company started their pilot production in March 2009 and plan to start mass production of thin-film amorphous silicon modules in the second half of 2009, with 25 MW capacity. The next expansion was planned in 2012, with an emerging technology of amorphous and microcrystalline silicon (μc-Si), and the capacity is expected to exceed 150 MW in 2013. A further expansion to more than 600 MW is planned for 2014. For 2011, a production of 12 MW is estimated [Pho 2012].

- **Sunwell Solar Corporation**, a subsidiary of CMC Magnetics Corporation, Taiwan's top compact disc maker, contracted a 45 MW thin-film PV production plant with Oerlikon Solar. The plant started production at the beginning of September 2008. According to the company, the current production capacity is 60 MW.

For 2011, a production of 50 MW is reported [Pho 2012].

- **Taiwan Semiconductor Manufacturing Company, Ltd.** (TSMC) signed a technology licensing, supply, and joint development agreement with the Stion Corporation (USA). Under the agreements, Stion licenses and transfers its thin-film CIGSS technology to TSMC, while TSMC will provide a certain quantity of solar modules to Stion, using the technology. TSMC Solar will manufacture CIGS thin-film modules and plans to reach a production capacity of 1 GW in the next 3-5 years. Construction began on the first production facility in September 2010 in Taichung, Taiwan. The facility was scheduled to enter commercial production in Q2 2012 and reach volume production of 200 MW per year in thin-film photovoltaic modules by the end of 2012. A second phase is planned, which will expand production to over 700 MW.

- **Top Green Energy Technologies Inc.** was established in January 2006 by Powercom. The company produces silicon solar cells and invested in the upstream polycrystalline silicon production with a modified Siemens manufacturing process. They broke ground for the factory at “Chang Pin Industrial Park” in May 2009. According to the company, they have a production capacity of 120 metric tons polysilicon, 550 metric tons solar ingots and 108 MW solar cells. Solar cell production in 2011 was estimated at 47 MW [Enf 2012].

- **Unitech Solar** was founded by United Printed Circuit Board (UPCB) in 2008 and started mass production with a 30 MW line in Yilan County of Eastern Taiwan in June 2008. According to the company, production increased to 150 MW in 2011 and a further expansion to 330 MW is planned in 2012. For 2011, a production of 80 MW is reported [Pho 2012].

9.2.13 Taiwan Polysilicon Corporation

Taiwan Polysilicon Corp. was set up by LCY Chemicals in 2007 and started to build a polysilicon factory in Pingtun, Taiwan, in 2008. In 2011, the plant had a capacity of 8,000 metric tons and a new plant with 20,000 metric tons was started.

10. United States

In 2011, the USA more than doubled their annual installations and installed about 1.85 GW of new PV electricity generation capacity and increased cumulative capacity to almost 4.4 GW. Utility PV installations more than tripled again and reached 754 MW in 2011. The top ten States – California, New Jersey, Arizona, New Mexico, Colorado, Pennsylvania, New York, North Carolina, Texas and Nevada, accounted for more than 87% of the US grid-connected PV market [Sei 2012].

PV projects with Power Purchase Agreements (PPAs), with a total capacity of 9 GW, are already under contract and to be completed by 2016. Over 3 GW of these projects are already financed and under construction [Sei 2012]. If one adds the over 30 GW of projects in an earlier planning stage, which are actively seeking permits, interconnection agreements, PPAs and finance, the pipeline stands at 39 GW.

10.1 Policies supporting PV

Many State and Federal policies and programmes have been adopted to encourage the development of markets for PV and other renewable technologies. These consist of direct legislative mandates (such as renewable content requirements) and financial incentives (such as tax credits). One of the most comprehensive databases about the different support schemes in the US is maintained by the Solar Centre of the State University of North Carolina. The Database of State Incentives for Renewable Energy (DSIRE) is a comprehensive source of information on State, local, utility, and selected Federal incentives that promote renewable energy. All different support schemes are described there and it is highly recommended to visit the DSIRE web-site http://www.dsireusa.org/ and the corresponding interactive tables and maps for details.

After years of political deadlock and negotiations concerning the support of renewable energies in the USA, things started to move in 2005. The main breakthrough was reached when the 2005 Energy Bill was passed by the Senate on 29 July 2005 and signed by President Bush on 8 August 2005.

The second milestone was the final approval of the Californian “Million Solar Roofs Plan” or Senate Bill 1 (SB1), by the Californian Senate on 14 August 2006, and the signature by Governor Schwarzenegger on 21 August 2006.

On 17 February 2009, President Obama signed the American Recovery and Reinvestment Act (ARRA) into law. The main solar provisions that are included in this bill are:

- The creation of a Department of Treasury Grant Programme (TGP).
- Improvement to the investment tax credit by eliminating ITC penalties for subsidised energy financing.
- A new DoE Loan Guarantee Programme.
- Create tax incentives for manufacturing, by offering accelerated depreciation and a 30% refundable tax credit for the purchase of manufacturing equipment used to produce solar material and components for all solar technologies (MITC).

Already in December 2009, the Solar Energy Industry Association (SEIA) published their new vision to supply 10% of the US electricity demand with photovoltaic electricity systems [Sta 2009]. Such a scenario would require a cumulative installed capacity of 350 GW in 2020 and is similar to the European vision (Fig. 16). This vision is significantly higher than the base-line scenario, which adds up to roughly 150 MW, or 4.3% in 2020, or the 84 GW of photovoltaics and concentrated solar power plants, as outlined in the "A Solar Grand Plan" for the US, published in 2007 [Zwe 2007]. However, for all scenarios it would be necessary to start with laying the foundation of the necessary High Voltage Direct Current (HVDC) transmission system now.

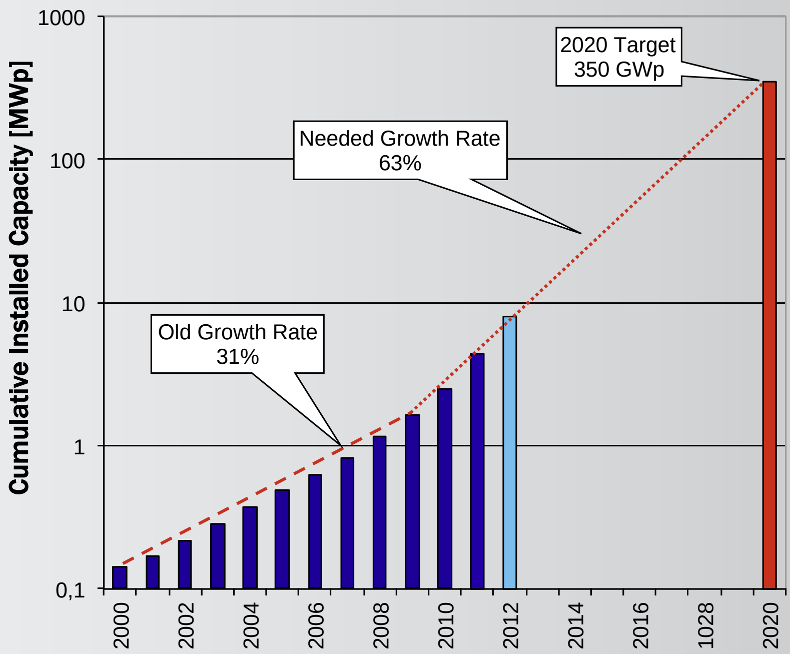
In May 2010, SEIA published a study evaluating the effects of a prolongation of the TGP and MITC on additional job creation and solar installations between 2010 and 2016, compared to the base-line scenario [Eup 2010]. The results are an additional 6.2 GW of PV installations between 2010 and 2016 and more than 160,000 additional new PV related jobs.

The average residential electricity price over the 12 months from August 2011 to July 2012 was 11.90 ct/kWh, about 1.9% higher than the 11.68 ct/kWh the 12 months period before. Figure 18 shows the nation-wide figures for this average residential electricity price.

PV electricity system prices have decreased considerably over the last years, but the world market prices are not wholly reflected in local support schemes. Taking the electricity prices for consumers and the available solar radiation as a base, the residential US market for grid-connected systems can be classified into four categories without incentives if an investment pay-back of 30 years is assumed. The calculation was performed by the National renewable Energy Centre (NREL) [Nre 2012]. It should be noted that this is a simplified categorisation and conditions in a State might vary due to solar radiation, weather conditions or individual system performance. Nevertheless, it indicates at what unsubsidised turn-key prices for a PV system PV electricity production is already now (without considering further electricity price increases) competitive with residential electricity prices.

Figure 17 shows in different colours which system cost leads to Levelised Costs of Energy (LCOE) for electricity from PV systems which are the same or lower than the residential electricity retail rate.

Fig. 16: SEIA vision for 10% solar electricity in 2020 (2012 figures are estimates).



According to the Solar Energy Industry Association, the PV system prices for residential systems have decreased from 6.28 $/W (4.83 €/W) in the second quarter of 2011 to 5.46 $/W (4.20 €/W) in the second quarter of 2012 [Sei 2012a]. These price reductions are far less than in the non-residential (2Q 2011: 5.20 $/W (4.00 €/W), 2Q 2012 4.38 $/W (3.37 €/W)) or utility sector (2Q 2011: 3.75 $/W (2.88 €/W), 2Q 2012 2.60 $/W (2.00 €/W)) and are attributed to a higher proportion of soft costs, which decline far slower than hardware component costs.

A recent comparison of the Lawrence Berkley National Laboratory (LBNL) revealed that the 2011 difference in hardware costs between Germany and the USA was 0.47 €/Wp (0.36 €/Wp), but the difference in soft costs and profit amounted to 2.72 $/Wp (2.09 €/Wp) [See 2012]. These two cost factors led to the situation that the soft costs for residential PV systems in the USA were 3.34 $/Wp (2.56 €/Wp) or more than the total average for an installed residential PV system in Germany.

If PV system prices would be the same like in Germany in 2011 (3 $/kW, 2.3 €/kW), electricity generated from PV systems would already be cost competitive in already 6 states (Hawaii, California, Connecticut, New Jersey, New York and Nevada) without any incentive and the German Q3 2012 prices for residential systems below 10 kW (1.85 €/W or 2.41 $/Wp) would open the market in a large number of the 26 states in the next (orange) class [BSW 2012a]. Once the targets of the **SunShot Initiative** are reached, electricity from PV systems in all 50 States would be competitive to electricity household retail prices.

To lower the permitting costs for small residential systems, Vermont enacted a first-in-the-US registration process for small solar systems, providing a national model for mitigating costly local solar permitting. Bill H.56, signed into law on 25 May 2011, coming into effect in January 2012, establishes a simple registration process for solar systems with a maximum power of 5 kW. The process, which replaces the existing permitting, allows solar customers to install the system ten days after completing a registration form and certificate of compliance with interconnection requirements. The utility has ten days to raise any interconnection issues, otherwise a Certificate of Public Good is granted and the project may be installed.

10.2 Incentives supporting PV

Due to the political situation in the US, there are no uniform implementation incentives for photovoltaics. Many State and Federal policies and programmes have been adopted to encourage the development of markets for PV and other renewable technologies. These consist of direct legislative mandates (such as renewable content requirements) and financial incentives[35] (such as tax credits). Financial incentives typically involve appropriations or other public funding, whereas direct mandates typically do not. In both cases, these programmes provide important market development support for PV. The types of incentives are described below. Amongst them, investment rebates, loans

[35] DoE has defined a financial incentive as one that: (1) transfers economic resources by the Government to the buyer or seller of goods or a service that has the effect of reducing the price paid or increasing the price received; (2) reduces the cost of producing the goods or service; and/or (3) creates or expands a market for producers [Gie 2000].

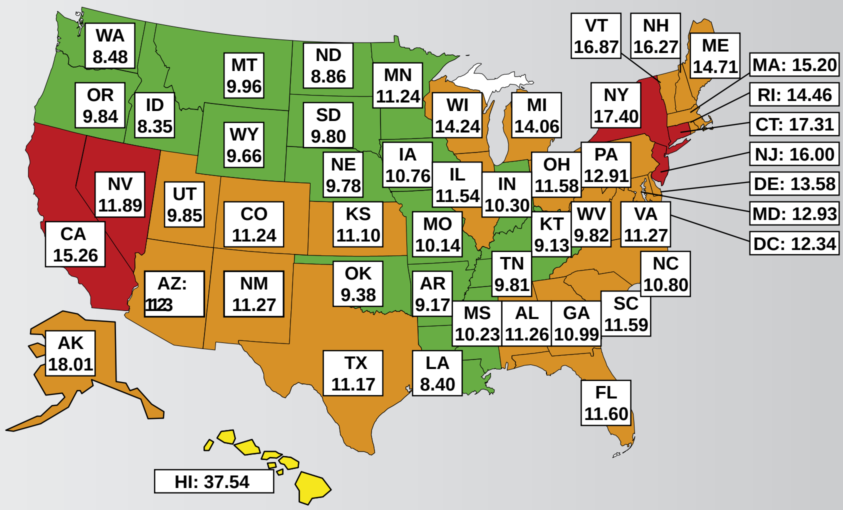
Fig. 17: Average residential electricity prices (¢/kWh) for 1H 2012 [Eia 2012].

System price 4 $/Wp – 1 State:
Hawaii

System price 3 $/Wp – 5 States:
California, Connecticut, New Jersey, New York, Nevada

System price 2 $/Wp – 26 States + Washington DC:
Alabama, Alaska, Arizona, Colorado, Delaware, Florida, Georgia, Illinois, Kansas, Main, Maryland, Massachusetts, Michigan, New Hampshire, New Mexico, North Carolina, Ohio, Pennsylvania, Rhode Island, South Carolina, Texas, Utah, Vermont, Virginia, West Virginia, Wisconsin

System price 1 $/Wp – 18 States:
Arkansas, Idaho, Indiana, Iowa, Kentucky, Louisiana, Minnesota, Mississippi, Missouri, Montana, Nebraska, Oklahoma, Oregon, North Dakota, South Dakota, Tennessee, Washington, Wyoming.



and grants are the most commonly used – at least 39 States, in all regions of the country, have such programmes in place. The most common mechanisms are:

- personal tax exemptions (Federal Government, 23 States + Puerto Rico)
- corporate tax exemptions (Federal Government and 25 States)
- sales tax exemptions for renewable investments (28 States + Puerto Rico)
- property tax exemptions (37 States + District of Columbia, Puerto Rico, 14 local)
- buy-down programmes (15 States + District of Columbia, Puerto Rico, Virgin Islands, 471 utilities, 16 local)
- loan programmes and grants (Federal Government, 44 States + District of Columbia, Virgin Islands; 69 utilities, 37 local, 9 private)
- industry support (24 States + Puerto Rico, 1 local)

One of the most comprehensive databases about the different support schemes in the US is maintained by the Solar Centre of the State University of North Carolina. The Database of State Incentives for Renewable Energy (DSIRE) is a comprehensive source of information on State, local, utility, and selected Federal incentives that promote renewable energy [Dsi 2012]. All different support schemes are described there and it is highly recommended to visit the DSIRE web-site http://www.dsireusa.org/ and the corresponding interactive tables and maps for more details.

The US State Renewable Portfolio Standards are a major driver behind the rapid development of utility scale PV projects in the USA. The current US RPSs collectively require that electricity generation by non-hydro renewables should more than double by 2025. The target is to supply about 9% of the US electricity, up from the approximately 4% of non-hydro renewable electricity in 2009 [Eia 2012a, Dsi 2012]. However, the use of Power Purchase Agreements (PPAs) to fulfil RPSs has also led to the use of this instrument in States which do not have an RPS.

In 2009 the Union of Concerned Scientists predicted that State RPS and Renewable Energy Funds could lead to the development of 76,750 MW of new renewable production capacity by 2025. This would be an increase of more than 570% compared to the total US RE capacity in 1997 (excluding hydro) [Uni 2009]. The commitment to increase renewable energy use at State level will have a significant impact on reducing CO2 emissions. By 2025, these State RPSs will reduce total annual CO2 emissions by more than 183 million metric tons of CO2, which is the equivalent of taking 30 million cars off the road.

The benefits at State level do not only include the significant reduction of greenhouse gas emissions, but they are also an effective means to diversify energy supply sources, increase energy security and create local jobs and economic benefits. The latter reasons are probably behind the fact that a number of States have recently revisited and significantly increased or accelerated their annual requirements.

In October 2012, 29 States, the District of Columbia, North Mariana Islands and Puerto Rico had Renewable Portfolio Standards, whereas eight additional States, Guam and Virgin Islands have State Goals (Fig. 18).

In 16 States and the District of Columbia, the RPS include minimum solar or distributed generation (DG) provisions (Fig. 19). It is interesting that 15 other States and DC have followed the Colorado RPS with a specific target for solar electricity. In addition, a number of States have provisions in their RPS which counts electricity from PV systems with a higher multiplier. The RPS laws in California and New York create the two largest markets for new renewable energy growth.

Another very important measure for photovoltaics is the grid access. In August 2012, 43 US States, Washington DC, American Samoa, Guam, Puerto Rico and the Virgin Islands had implemented a net metering policy (Fig. 20). In Idaho, South Carolina and Texas some utilities have agreed on voluntary net metering.

At least 22 States, DC and Puerto Rico authorise or allow 3rd party solar PPAs (Fig. 21). A third-party power purchase agreement is a model, which allows a developer to build and own a PV system on the customer's property and sell the power back to the customer. In addition, the third-party PPA model enables the customer to support solar power while avoiding most or all initial costs, as well as responsibilities for operations and maintenance, for both of which the developer is responsible.

Fig. 18: States with Renewable Portfolio Standards in the US (June 2011);
Figure © DSIRE [Dsi 2012].

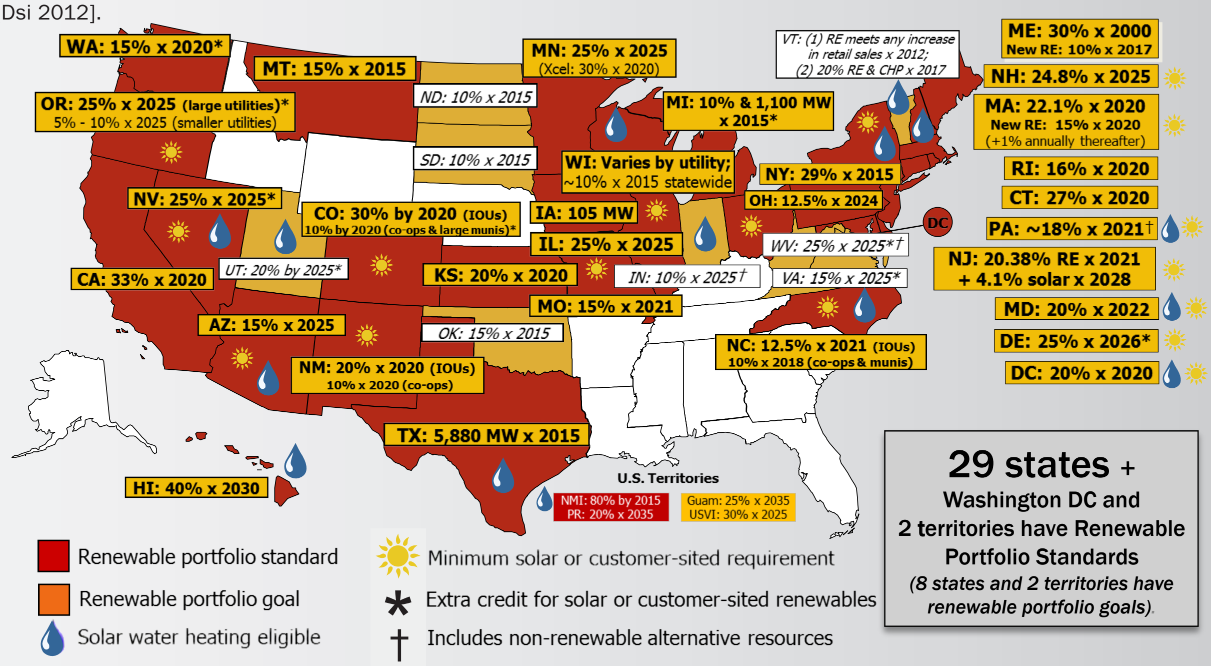


Fig. 19: US States with RPS Policies with Solar/DG Provisions (October 2012);
Figure © DSIRE [Dsi 2012].

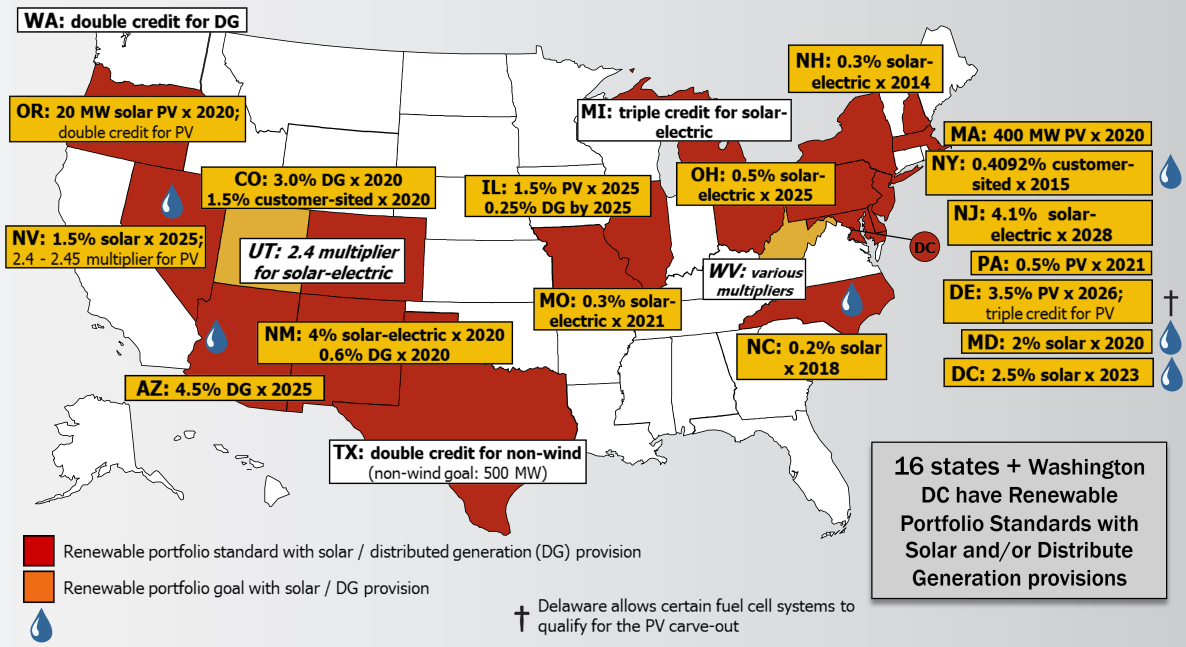


Fig. 20: US States with Net-metering in the US (August 2012) and upper limits;
Figure © DSIRE [Dsi 2012].
Note: Numbers indicate individual system capacity limit in kW.
Some limits vary by customer type, technology and/or application.
Other limits might also apply.

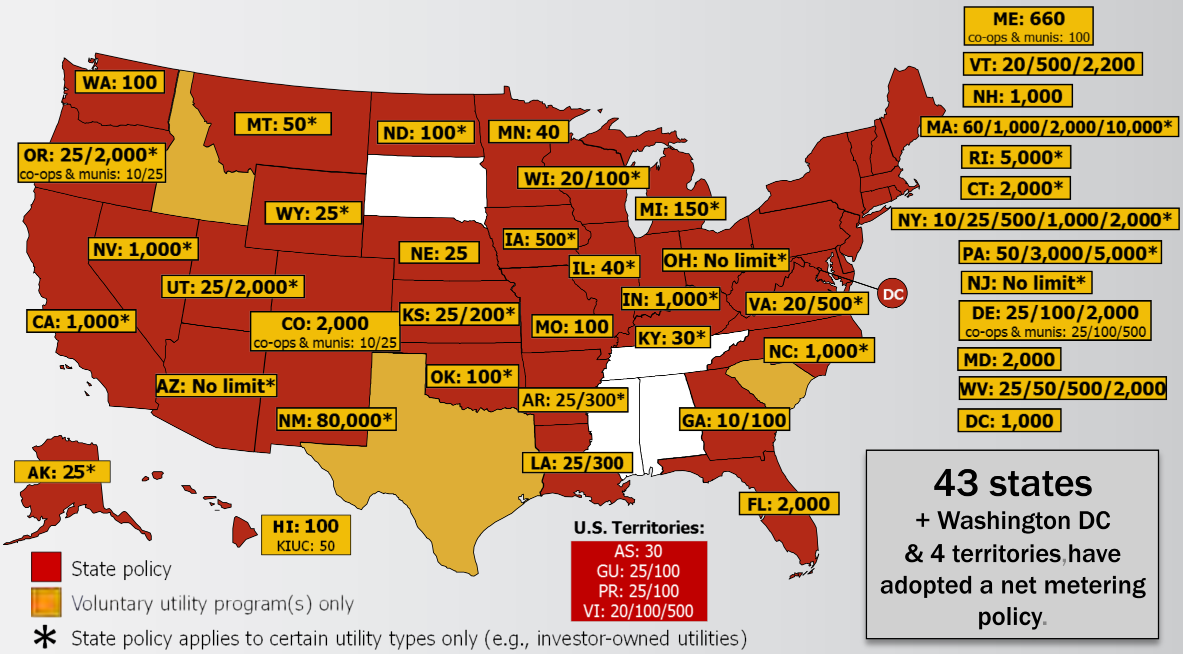
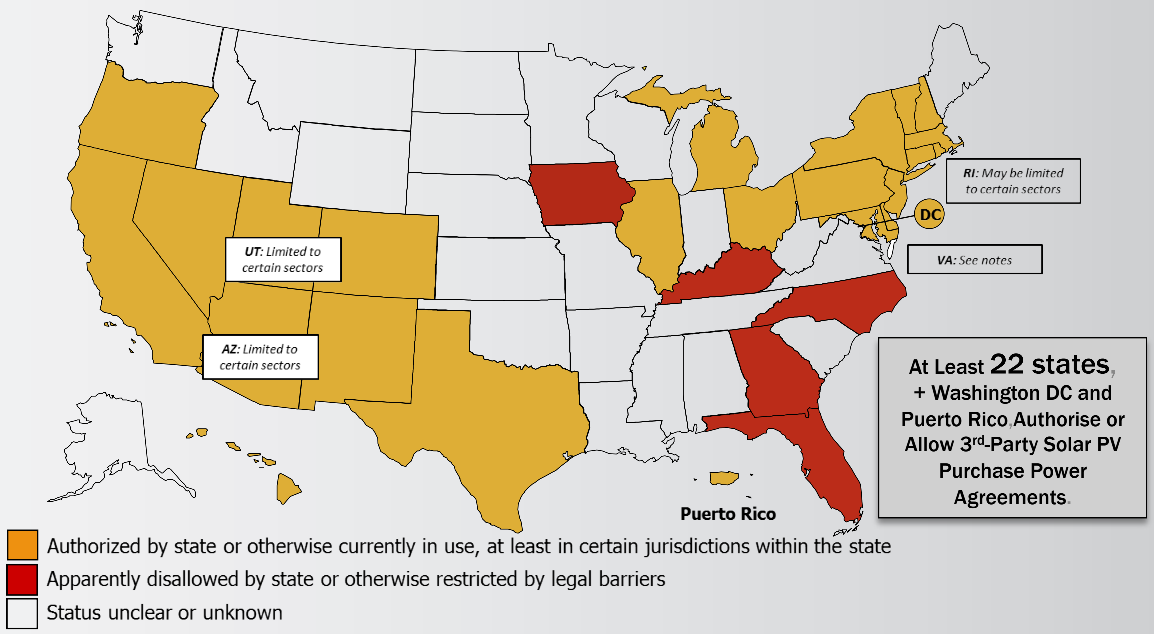


Fig. 21: US States which authorise or allow 3rd party solar PPAs in the US (August 2012);
Figure © DSIRE [Dsi 2012].



10.3 Solar Programmes

10.3.1 Solar Energy Technologies Programme

The aim of the US Solar Energy Technologies Programme (SETP or Solar Programme) is to develop cost-competitive solar energy systems for America. The current Multiannual Work-Programme runs from 2008 to 2012 [DoE 2008]. More than $170 million (€130.8 million) are spent each year for research and development on the two solar electric technologies which are considered to have the greatest potential to reach cost competitiveness by 2015: photovoltaics and concentrating solar power. The programme names as the greatest R&D challenges the reduction of costs, improvement of system performance, and the search for new ways to generate and store energy captured from the sun.

The Solar Programme also aims to ensure that the new technologies are accepted in the market-place. Work is done to remove many non-technical market barriers, such as updating codes and standards that aren't applicable to new technologies, improving interconnection agreements among utilities and consumers, and analysing utility value capacity credits for utilities. Such activities should help consumers, businesses, and utilities to make more informed decisions when considering renewable energy, and they also facilitate the purchase of solar energy.

The Solar Programme conducts its key activities through four sub-programmes:

- Photovoltaics
- Concentrated Solar Power
- Systems Integration
- Market Transformation.

The 2008-2012 time-frame emphasises the following areas:

1. Fully incorporating concentrating solar power (CSP) efforts into the Solar America Initiative (SAI).
2. Improving storage technologies for both CSP and PV technologies.
3. Better integrating solar technologies into the electric grid, in both distributed and centralised generation applications.
4. Eliminating city and State level technical and regulatory barriers to solar technology deployment.
5. Improving the ability of DoE and its laboratories and partners to quickly and effectively transfer R&D concepts from basic to applied science and then to the market-place.
6. Exploring and developing the next generation of PV technologies that will reach consumers beyond the SAI time-frame (post-2015).
7. Assisting US industry in regaining its leadership role in the global solar market-place.
8. Promoting increased understanding of environmental and organisational safety across all Solar Programme activities by all participants.

The Solar Programme goals support the DoE 2006 Strategic Plan [DoE 2006], which identified five strategic themes, amongst them energy security, which is a key driver of the Solar Programme activities supported by the DoE. In addition, the Programme supports the research and development provisions and broad energy goals outlined in the National Energy Policy Act 2005 (EPAct 2005) and the Energy Independence and Security Act (EISA). In both Acts, Congress expressed strong support for decreasing dependence on foreign energy sources and decreasing the cost of renewable energy generation and delivery. Support from Congress and State Governments, and the availability

Table 2: Solar Programme Cost Targets by Market Sector

Market Sector	Current U.S. Market Price Range for Conventional Electricity(¢/kWh)	Levelised Cost of Energy (¢/kWh)		
		Benchmark	Target	
		2005	2010	2015
Utility	1.96 – 26.27 [b] 4.08 – 31.17 [c]	13–22	13–18	5–7
Commercial [a]	6.76 – 35.29 [c]	16–22	9–12	6–8
Residential	8.35 – 37.54 [c]	23–32	13–18	8–10

a) In many commercial applications, utility costs are tax deductible. In these cases, the cost of solar energy should be compared to the effective market price, considering tax effects.
b) 2012 (January – June 2012) Weighted Average Wholesale Day Ahead Prices at Selected Hubs, Peak on ICE platform [Eia 2012].
c) Average retail electricity price for January to July 2012 [Eia 2012].

of financial incentives, are important for achieving the Solar Programme goals.

The Solar Programme lists economic targets for PV (Table 2), which were determined by an analysis of key markets. They were set based on assessments of the Levelised Costs of Energy (LCOE) for solar technologies to be competitive in these markets.

According to the Solar Programme, the residential and commercial price targets are based on current retail electricity prices and take into consideration the rather optimistic projection of the Energy Information Administration (EIA) that electricity prices will remain fairly constant (in real terms) through 2025. With these assumptions, the Programme predicts that meeting the solar market cost goals will result in 5-10 GW of PV installed by 2015 and 70-100 GW by 2030 in the US.

Ten photovoltaic technology roadmaps were developed in 2007 by staff at NREL, Sandia National Laboratories, DoE, and experts from universities and private industry [DoE 2008a]. This work was done, in part, to support activities within the Solar America Initiative. These technology roadmaps summarise the current status and future goals for the specific technologies.

10.3.2 Solar Technology Research Plan

The US strategy, for overcoming the challenges and barriers to massive manufacturing, sales, and installation of PV technology, is to achieve challenging targets throughout the development pipeline. Multiple technologies are being pursued that are at differing stages of maturity. With an effective combination of the talents in industry, university, and national laboratories, the needed cost, performance and reliability goals should be achieved. Specific PV R&D efforts toward achieving these goals include:

1. PV Systems & Module Development
2. PV Materials & Cell Technologies
3. Testing & Evaluation
4. Grid / Building Integration

The PV sub-programme's R&D activities were already described in the 2010 Report [Jäg 2010].

10.3.3 Advanced Research Projects Agency – Energy (ARPA-E)

In 2006, the National Academies released a report "Rising Above the Gathering Storm", where it recognised the need to re-evaluate the way the United States spurs innovation. The report included the recommendation to establish an Advanced Research Projects Agency – Energy (ARPA-E) within the Department of Energy (DoE), which was realised in 2007.

ARPA-E is modelled after the successful Defense Advanced Research Projects Agency (DARPA), the Agency responsible for technological innovations such as the Internet and the stealth technology. Specifically, ARPA-E was established and given the following objectives:

1. To bring a freshness, excitement, and sense of mission to energy research that will attract many of the US's best and brightest minds — those of experienced scientists and engineers, and, especially, those of students and young researchers, including persons in the entrepreneurial world;

2. To focus on creative "out-of-the-box" transformational energy research that industry by itself cannot or will not support, due to its high risk, but where success would provide dramatic benefits for the nation;

3. To utilise an ARPA-like organisation that is flat, nimble, and sparse, capable of sustaining for long periods of time those projects whose promise remains real, while phasing out programmes that do not prove to be as promising as anticipated; and

4. To create a new tool to bridge the gap between basic energy research and development/industrial innovation.

In April 2011, ARPA-E launched a call for funding (Funding Opportunity Announcement) "Solar Agile Delivery of Electrical Power Technology (Solar ADEPT)". The motivation for the call is described as follows:

SunShot leverages the unique strengths across DOE to reduce the total cost of utility-scale solar systems by 75 percent by 2017. If successful, this collaboration would deliver solar electricity at roughly 6 cents a kilowatt hour – a cost competitive with electricity from fossil fuels. This would enable solar electricity to scale without subsidies and make the U.S. globally competitive in solar technology. ARPA-E's portion of the collaboration is the Solar ADEPT program, which focuses on integrating advanced power electronics into solar panels and solar farms to extract and deliver energy more efficiently. Specifically, ARPA-E aims to invest in key advances in magnetics, semiconductor switches, and charge storage, which could reduce power conversion costs by up to 50 percent for utilities and 80 percent for homeowners.

The objectives of the call, which has a funding volume of about $10 million (€7.7 million) are the following:

This FOA is primarily focused on the development of advanced component technologies, converter architectures, and packaging and manufacturing processes with the potential to improve the performance and lower the cost of photovoltaic systems. Specifically, four categories of performance and integration level will be considered.

Category 1 seeks to broaden the application space for fully-integrated, chip-scale power converters for sub-module integrated applications. The performance of integrated converters must scale from today's 1W class chips to 10-80W class converters. Technologies for chip-scale DC/DC converter with Maximum Power Point Tracking (MPPT) that can be integrated during module assembly are of particular interest.

Category 2 seeks to broaden the application space for package integrated microconverters by reducing the size and improving component and package performance. The existing state-of-the-art for microinverters requires large (as high as 500) numbers of discrete components to achieve high efficiency over the full-operating range as defined by California Energy Commission (CEC). Highly integrated DC/AC converters with total part-counts less than 10 are required.

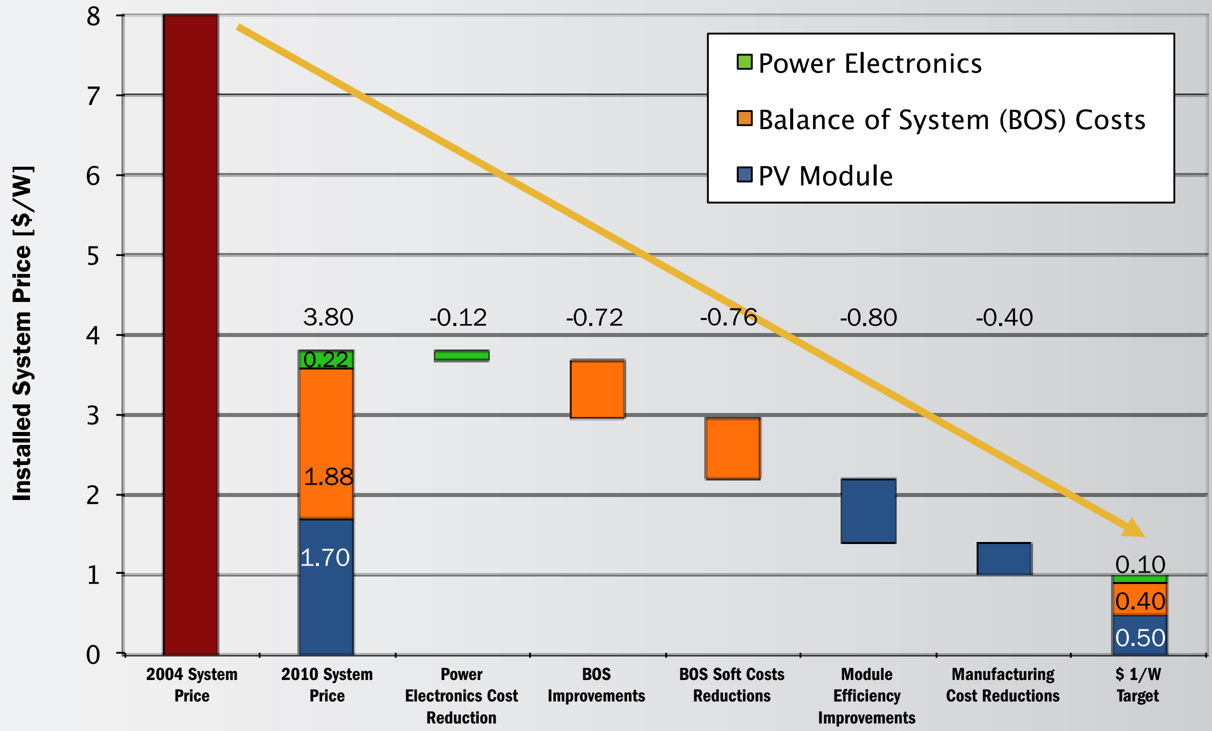
Category 3 addresses lightweight inverters for commercial roof-top and wall-mount applications. State-of-the-art inverters weigh in excess of 250 lbs for 100kW. Reducing the inverter weight simplifies siting of inverters for small to medium sized commercial buildings – allowing the inverters to be rooftop mounted or wall-mounted within an instrument room. High performance component and circuit architectures will be required to realise dramatic (> 6x) improvements in power densities.

Category 4 addresses lightweight, solid-state, medium voltage energy conversion for high power applications such as utility-scale inverters with direct grid connection. To address these applications, new solid-state switch technology at voltages exceeding 13kV and advanced magnetics technology supporting MW scale power converters with multi-kilohertz frequencies are of particular interest.

10.4 Sun Shot Initiative

February 2011, Energy Secretary Steve Chu, formally unveiled the Sun Shot Initiative, which is labelled after President Kennedy's famous moon shot speech in 1962. According to the DoE, it is a collaborative national initiative to make solar energy technologies cost-competitive with other forms of energy by reducing the cost of solar energy systems by about 75% before 2020.

Fig. 22: Price Reduction Targets of the SunShot Initiative



The aim of the initiative is to accelerate and advance existing DoE research efforts by refocusing its solar energy programs – valued at approximately $200 million (€154 million) per year – to make large-scale solar energy systems cost competitive without subsidies by the end of the decade.

Figure 22 shows the price reduction targets of the SunShot Initiative.

10.5 Solar Companies

In the following chapter those solar companies not yet mentioned in Chapter 3 are described briefly. This listing does not claim to be complete, especially due to the fact that for some companies, information or data were very fragmented. Data were collected from the companies' web-sites. A lot of start-up companies are missing, due to sparse and sometimes contradictory information.

10.5.1 Abound Solar, Inc.

Abound Solar (formerly AVA Solar) was founded in 2007 to commercialise the manufacturing of cadmium telluride (CdTe) thin-film photovoltaic modules. In November 2009, the company started mass production at their factory in Longmount (CO). According to the company, the manufacturing capacity was 65 MW at the end of 2011. In February 2012, the company stopped production and filed for insolvency in June 2012. For 2011, a production of 40 MW is reported [Pho 2012].

10.5.2 GE Solar

PrimeStar Solar was founded in 2006 to manufacture CdTe solar cells. In September 2007, GE Energy, took a minority equity position in PrimeStar Solar and became a majority shareholder in June 2008. The company has a 30 MW manufacturing line in Arvada, CO. In April 2011, GE Energy announced not only the completion of the acquisition of PrimeStar, but its plans to build a 400 MW manufacturing facility. In May 2012, the company announced the postponement of the factory construction without a new date set.

10.5.3 Global Solar Energy Inc.

GSE is located in Tucson and was established in 1996. The company is producing thin-film photovoltaic CIGS solar cells for use in solar products, as well as installing and managing large solar photovoltaic systems. According to the company, the new 40 MW plant was opened in March 2008 and a 35 MW plant in Germany opened in the autumn of 2008. Due to the worldwide overcapacity, the German operations filed for insolvency in June 2012. In 2011, a production of 40 MW (30 MW USA, 10 MW Germany) is reported [Pho 2012].

10.5.4 Miasolé

Miasolé was formed in 2001 and produces flexible CIGS solar cells on a continuous, roll-to-roll production line. According to the company, the current manufacturing capacity of 50 MW will be increased to 150 MW at the end of 2012. In September 2012, the company announced its takeover by Hanergy (PRC). For 2011, a production of 60 MW is reported [Pho 2012].

10.5.5 Suniva Inc.

Suniva was founded in 2007 by Dr. Ajeet Rohatgi, Director of Georgia Tech's University Center of Excellence for Photovoltaic Research and Education. On 4 November 2008, the company announced the start of production at their 32 MW factory in Norcross (GA). In 2009, the capacity was increased to 96 MW and to 170 MW in 2010. For 2011, a production of 170MW is reported [Pho 2012].

10.5.6 Additional Solar Cell Companies

- **AQT Solar Inc.** was founded in 2007 to manufacture CIGS thin-film solar modules and opened its first manufacturing plant with 15 MW capacity in Sunnyvale, California, in August 2010. Early 2010, the company announced to build a second factory in Carolina Pines, North Carolina with about 30 to 40 MW. Production should have started in 2012, but the company filed for insolvency in 2012.

- **Ascent Solar Technologies Incorporated** was established in 2005 to manufacture CIGS thin-film solar modules with a roll-to-roll process. A 30 MW production line was completed in 2009 and was planned to ramp-up to full capacity during 2010. In 2011, TFG Radiant Group invested in the company and doubled its share to 41% early 2012. For 2011, a production of 10 MW is reported.

- **HelioVolt** was founded in 2001 with the aim to develop and commercialise its FASST® process for applying CIGS thin-film photovoltaics directly onto conventional construction materials. The company operates a pilot line in Austin, TX, and started commercial production in 2011. In September 2011, the Korean SK Group invested into the company. For 2011, a production of 10 MW is estimated [Pho 2011].

- **Nanosolar** was founded in 2001 and is based in Palo Alto. It is a privately held company with financial-backing of private-technology-investors. According to the company, Nanosolar's current production capacity is in excess of 100 MW. Production for 2011 is reported with 10 MW [Pho 2012].

- **Power Films Inc.** was founded in 1988 to develop and manufacture thin-film silicon solar cells. The company announced, in its 2008 first half-year report, that it continues to make progress with its strategic objective of achieving 10 MW production capacity by the end of 2009, and 24 MW of capacity by the end of 2010.

- **Solar Junction** based in San Jose, CA, was founded in 2007 and develops high efficiency III-V multi-junction solar cells. For 2011, a production capacity of 14 MW and a production of 1 MW is reported [Pho 2012].

- **Solo Power Inc.**, founded in 2006, is a California-based manufacturer of thin-film solar photovoltaic cells and modules based on CIGS. In June 2009, the company received certification under ANSI/UL 1703 standard. In February 2011, the company announced that it had received a conditional commitment from the U.S. Department of Energy (DOE) Loan Programs Office for a $197 million (€152 million) loan guarantee. The company plans to construct a new manufacturing plant which, when completed and at full capacity, is expected to produce approximately 400 MW of thin-film modules annually. For 2011, a production of 4 MW is estimated [Pho 2012].

- **SpecraWatt** was formed from assets spun out of Intel Corporation in June 2008. In 2009, the company built its first solar cell factory in Hopewell Junction, NY, which is capable of housing over 200 MWp of capacity. Production started on the first 60 MW manufacturing line in 2010. In 2011, the company filed for insolvency.

- **Stion** was founded in 2006 to manufacture CIGS solar cells and is headquartered in San Jose, CA. According to the company, its manufacturing capacity in San Jose should be expanded to 140 MW at the end of 2011. In January 2011, the company announced the building of another 100 MW manufacturing plant in Hattiesburg, MS, which should have shipped its first modules in March 2012. In December 2011, the company received a substantial equity investment by AVACO and Korean equity funds. According to press reports, Stion will set up a Korean subsidiary and construct a thin-film photovoltaic module factory in the Seongseo Industrial Complex in Daegu, Korea by 2014 [Kor 2012].

- **Xunlight Corporation** is a technology spin-off from the University of Toledo (OH) to develop and manufacture flexible and lightweight thin-film silicon solar modules. In 2009, the company completed the installation of its first 25 MW roll-to-roll photovoltaic manufacturing equipment. In 2011, a production of 5 MW is estimated [Pho 2012].

10.5.7 AE Polysilicon Corporation

AE Polysilicon (AEP) was founded in 2006 to manufacture polysilicon for the solar industry. The main investors are Motech (33.3%) and since 2010 Total Gas & Power USA (25.4%). On 19 February 2008, the company broke ground on its production facility at its site at the Keystone Industrial Port Complex (KIPC) in Fairless Hills (PA). In May 2010, AEP announced that it expects to complete fluidised bed reactor (FBR) testing and begin commercial production in the coming months. The company expected to ramp up the initial facility to full capacity (1,800 tons) by late 2011. However, due to the rapid price decline of polysilicon, Motech decided to close down its subsidiary and the equipment was put up for auction in July 2012.

10.5.8 Silicor Materials

The company was founded as Calisolar in 2006 and started commercial shipments of solar cells in January 2010. In February 2010, the company acquired 6N Silicon Inc., an Ontario-based polysilicon manufacturer with a 2,000 ton/year capacity. According to the company, it is expanding its polysilicon production capacity, but stopped solar cell production in 2011.

11. Outlook

In 2011, world-wide new investments into the renewable energy and energy efficiency sectors increased to a new record of $263 billion (€202 billion), including $25.8 billion (€19.8 billion) research and development spending [Pew 2012]. For the second year in a row, solar power attracted the largest amount of new investments into renewable energies and increased by 44% to $128 billion (€98.5 billion). Europe was still the leading region in terms of renewable energy investments, but renewable energy investments in the Asia/Oceania region again grew faster than in Europe, mainly through major investment increases in India, Japan and Indonesia.

With a growth of over 40%, the USA took the top rank with $48 billion (€36.9 billion), followed by China $45.5 billion (€35 billion), Germany $30.6 billion (€23.5 billion) and Italy $28 billion (€21.5 billion) [Pew 2012].

At the end of 2011, about 73% or $141.6 billion (€108.9 billion) of the $194.3 billion (€149.5 billion) global "green stimulus" money from governments, aimed to help relieve the effect of the recession, had reached the markets [Pew 2012]. For 2012 another $35 billion (€26.9 billion) are expected.

The Photovoltaic Industry has changed dramatically over the last few years. China has become the major manufacturing place for solar cells and modules, followed by Taiwan, Germany and Japan. Amongst the 20 biggest photovoltaic manufacturers in 2011, only three had production facilities in Europe, namely First Solar (USA, Germany, Malaysia), Q-Cells (Germany and Malaysia) and REC (Norway and Singapore). However, REC closed down the production in Norway and First Solar has announced to close the factory in Germany by the end of the year. With the acquisition of Q-Cells by Hanwah Solar, it remains to be seen which production capacity will remain in Germany in the long run.

The focus of this report is on solar cells and modules, with some additional info about the polysilicon supply. Therefore, it is important to remember that the PV industry consists of more than that. and looking only at the cell production does not grasp the whole picture of the complete PV value chain. Besides the information in this report about the manufacturing of solar cells, the whole upstream industry (e.g. materials, polysilicon production, equipment manufacturing), as well as the downstream industry (e.g. inverters, BOS components, system development, installations) has to be looked at as well.

The implementation of the 100,000 roofs programme in Germany in 1990, and the Japanese long-term strategy set in 1994, with a 2010 horizon, were the beginning of an extraordinary PV market growth. Before the start of the Japanese market implementation programme in 1997, annual growth rates of the PV markets were in the range of 10%, mainly driven by communication, industrial and stand-alone systems. Since 1990 PV, production has increased by almost three magnitudes, from 46 MW to about 35 GW in 2011. This corresponds to a CAGR of a little more than 37% over the last twenty-one years. Statistically documented cumulative installations world-wide accounted for almost 70 GW in 2011. The interesting fact is, however, that cumulative production amounts to 90 GW over the same time period. Even if we do not account for the roughly 8 GW difference between the reported production and installations in 2011, there is a considerable 12 GW capacity of solar modules which are statistically unaccounted for. Parts of it might be in consumer applications, which do not contribute significantly to power generation, but the overwhelming part is probably used in stand-alone applications for communication purposes, cathodic protection, water pumping, street, traffic and garden lights, etc.

The temporary shortage in silicon feedstock, triggered by the high growth-rates of the photovoltaics industry over the last years, resulted in the market entrance of new companies and technologies. New production plants for polysilicon, advanced silicon wafer production technologies, thin-film solar modules and technologies, like concentrator concepts, were introduced into the market much faster than expected a few years ago. However, the dramatic price decline for polysilicon and solar modules of more than 50% over the last two years, triggered by the overcapacity for solar modules and polysilicon, has put enormous economic pressure on a large number of companies and is accelerating the consolidation of the industry. The benchmark was set by the Chinese Ministry of Industry and Information Technology, when it announced in February that it is aiming for an industry consolidation with polysilicon companies, having at least a production capacity of 50,000 metric tons for polysilicon, and solar cell manufacturers, with at least 5 GW production capacity by 2015 [MII 2012].

Especially companies in their start-up and expansion phase, with limited financial resources and restricted access to capital, are struggling in the current market environment. This situation is believed will continue for at least the next few years and put further pressure on the reduction of the average selling prices (ASP), but the speed of price reductions will slow. The continuation of the financial crisis added pressure as it resulted in higher government bond yields, and ASPs have to decline even faster than previously expected to allow for a higher project internal rate of returns (IRRs). On the other hand, the rapidly declining module and system prices already opened up new markets, and this development will continue and offers the perspectives for further growth of the industry – at least for those companies with the capability to expand and reduce their costs at the same pace.

Even with the current economic difficulties, the number of market implementation programmes world-wide is still increasing. This, as well as the overall rising energy prices and the pressure to stabilise the climate, will continue to keep the demand for solar systems high. In the long-term, growth rates for photovoltaics will continue to be high, even if economic frame conditions vary and can lead to a short-term slow-down.

This view is shared by an increasing number of financial institutions, which are turning towards renewables as a sustainable and stable long-term investment. Increasing demand for energy is pushing the prices for fossil energy resources higher and higher. Already in 2007, a number of analysts predicted that oil prices could well hit 100 $/bbl by the end of that year or early 2008 [IHT 2007]. After the spike of oil prices in July 2008, with close to 150$/bbl, prices have decreased due to the world-wide financial crisis and hit a low around 37$/bbl in December 2008. Since then, the oil price has rebounded and the IEA reported average prices for oil imports around 110 $/bbl since the second quarter of 2011, with a peak around 120 $/bbl in March and April 2012.

Oil demand has increased from about 84 million bbl/day in 1Q 2009, to around 90 million bbl/day in 2Q 2012, whereas the supply just increased from about 87 million bbl/day to 89 million bbl/day. For the rest of 2012 and 2013, modest demand growth of less than 1 million bbl/day is forecast, due to a combination of persistently high prices and a weak economic backdrop.

Even if no significant changes are forecasted by analysts at the moment for 2013, the fundamental trend, that increasing demand for oil will drive the oil price higher again, is still intact and will return as soon as the global economy recovers.

The Energy Watch Group estimated that world-wide spending on combustibles, fuels and electricity was between $5,500 billion (€4,231 billion) to 7,500 billion (€5,769 billion) in 2008 [Ewg 2010]. Between 2007 and 2010 about $1,840 billion (€1,415 billion) were spent on direct fossil fuel consumption subsidies and tax breaks according to a joint report of the IEA, OPEC, OECD, and World Bank [IEA

2011]. With 2007 to 2010 PV system prices, this subsidy would have been sufficient to install about 340 GW of PV systems world-wide. With the current system cost around 3 $/Wp (2.3 %/Wp), the amount would be sufficient to install 610 GW of photovoltaic electricity systems.

The FT cited Fatih Birol, Chief Economist at the IEA in Paris, saying that removing subsidies was a policy that could change the energy game "quickly and substantially". *"I see fossil fuel subsidies as the appendicitis of the global energy system which needs to be removed for a healthy, sustainable development future"* he told the FT [FiT 2010].

This is in line with the findings of a 2008 UNEP report Reforming Energy Subsidies [UNEP 2008], which concluded: *Energy subsidies have important implications for climate change and sustainable development more generally through their effects on the level and composition of energy produced and used. For example, a subsidy that ultimately lowers the price of a given fuel to end-users would normally boost demand for that fuel and the overall use of energy. This can bring social benefits where access to affordable energy or employment in a domestic industry is an issue, but may also carry economic and environmental costs. Subsidies that encourage the use of fossil fuels often harm the environment through higher emissions of noxious and greenhouse gases. Subsidies that promote the use of renewable energy and energy-efficient technologies may, on the other hand, help to reduce emissions.*

The joint study estimates that energy consumption could be reduced by 25 EJ (600 Mtoe) – or the combined current consumption of Japan and Australia - if the subsidies are phased out between now and 2020. The consumption cut would save the equivalent of the current carbon dioxide emissions of Germany, France, Italy, and Spain.

Over the last 20 years, numerous studies about the potential growth of the photovoltaic industry and the implementation of photovoltaic electricity generation systems were produced. In 1996, the Directorate-General for Energy of the European Commission published a study "Photovoltaics in 2010" [EC 1996]. The medium scenario of this study was used to formulate the White Paper target of 1997, to have a cumulative installed capacity of 3 GW in the European Union by 2010 [EC 1997]. The most aggressive scenario in this report predicted a cumulative installed PV capacity of 27.3 GW world-wide and 8.7 GW in the European Union for 2010. This scenario was called "Extreme scenario" and it was assumed that in order to realise it a number of breakthroughs in technology and costs, as well as continuous market stimulation and elimination of market barriers, would be required to achieve it. The reality check reveals that even the most aggressive scenario is lower than what we expect from the current developments. At the end of 2010, PV systems with a cumulative capacity of over 39 GW world-wide and over 29 GW in Europe were generating electricity. The installations increased further to almost 70 GW world-wide and 52 GW in Europe at the end of 2011.

After the massive cost reductions for the technical components of PV systems like modules, inverters BOS, etc. the next challenge is to lower the soft costs of PV system installations, like the permitting or financing costs. Despite the fact that PV system components are world-wide commodity products, the actual price for installed PV systems differs significantly. In the second quarter of 2012, the average system price for systems smaller 100 kWp was in the range of 1.78 €/Wp (2.3 $/Wp) in Germany, but between 6 and 6.5 $/Wp (4.6 – 5.0 €/Wp) in California and Japan [Blo 2012, Bsw 2012]. According to Bloomberg New Energy Finance (BNEF), one reason for the higher prices in California and Japan is the fact that installers are not passing on the full benefit of PV system price decline to their customers. BNEF expects a further price reduction there inline with the decrease of incentives. Engineering, Procurement and Construction (EPC) quotes for large systems are already much lower and turnkey system prices as low as 1 €/Wp (1.3 $/Wp) have been reported for projects to be finished in 2013 [Blo 2012].

In some countries, like Germany or Italy, the installed PV capacity will exceed 30% and 20% of the installed thermal power plant capacities respectively. Already on 25 May 2012, more than 22 GW of solar power were on the German grid, covering more than 30% of the total electricity demand at noon. Together with the respective wind capacities, wind and solar together will exceed 60% and 30% respectively. To effectively handle these high shares of renewable electricity, new technical and regulatory solutions have to be implemented in order not to run into the problem of curtailing large parts of this electricity. Besides conventional pumped storage options, electrical batteries are becoming increasingly interesting, especially for small-scale storage solutions in the low-voltage distribution grid. A recent business analysis for electric vehicles by McKinsey, showed that the current price of lithium-ion batteries in the range of 500 to 600 $/kWh (385 – 460 €/kWh) storage capacity could fall to 200 $/kWh (155 €/kWh) storage capacity in 2020 [Hen 2012]. Lithium-ion batteries have an average of 5,000 cycles which corresponds to a net kWh price of 0.10 to 0.12 $/kWh (0.077 to 0.093 €/kWh) now, and should fall to 0.04 $/kWh (0.03 €/kWh) in 2020.

With Levelised Costs of Electricity (LCOE) from PV systems reaching 0.14 to 0.17 $/kWh (0.11 to 0.13 €/kWh) in the third quarter of 2012 [Blo 2012b], the additional storage cost already makes sense in markets with high peak costs in the evening, where only a shift of a few hours is required. Already in February 2012, BYD (Build your Dreams) and the State Grid Corporation of China (SGCC) have finished construction on a large-scale utility project located in Zhangbei, Hebei Province, which combines 100 MW of wind power, 40 MW of solar PV electricity system, and 36 MWh of Li-ion energy storage.

According to investment analysts and industry prognoses, solar energy will continue to grow at high rates in the coming years. The different Photovoltaic Industry Associations, as well as Greenpeace, the European Renewable Energy Council (EREC) and the International Energy Agency, have developed new scenarios for the future growth of PV. Table 1 shows the different scenarios of the Greenpeace/EREC study, as well as the different 2011 IEA *World Energy Outlook scenarios* and the IEA PV Technology Roadmap.
It is interesting to note that the 2015 capacity values of the IEA Current Policy and 450ppm Scenarios (in red) are already reached or exceeded in 2011. With forecasted new installation of between 84 to 118 GW in 2012, 2013 and 2014 even the Greenpeace revolution scenario is no longer fictional thinking [Blo 2012].

These projections show that there are huge opportunities for photovoltaics in the future, if the right policy measures are taken, but we have to bear in mind that such a development will not happen by itself. It will require the constant effort and support of all stakeholders to implement the envisaged change to a sustainable energy supply with photovoltaics delivering a major part. The main barriers to such developments are perception, regulatory frameworks and the limitations of the existing electricity transmission and distribution structures.

The International Energy Agency's Energy Technology Perspectives 2010 stated that for their current Baseline Scenario, the overall investments in energy supply and use, for the period between 2010 and 2050, totals $270 trillion[36] (€208 trillion) [IEA 2010]. The BLUE-Map scenario, which would limit the concentration of Greenhouse Gases at 450 ppm, has an additional financing need of $46 trillion (€35.4 trillion), but at the same time the cumulative fuel savings of this scenario compared to the Baseline would be $112 trillion (€86.2 trillion), or more than twice the investment cost. This clearly indicates the huge societal benefit of a more aggressive climate change approach.

In the electricity sector, the investments for the baseline scenario over the next 40 years would amount to $23.5 trillion (€18.1 trillion) and about $15 trillion (€11.5 trillion) would be needed for new power-generation plants. The average BLUE-Map scenario has an additional financing need of $9.3 trillion (€7.2 trillion), mostly in power generation capacity.

It is worthwhile to mention that the high renewable BLUE Map scenario, with 75% electricity from renewable, has the highest additional investment cost of $12.9 trillion (€10 trillion), but this is less than 30 years of the average annual subsidies paid to fossil energy between 2007 and 2010.

[36] In 2010 U.S.$

Table 3: Evolution of the cumulative solar electrical capacities until 2050 [Gre 2012, IEA 2010a, IEA 2011a]

Year	**2010** [GW]	**2020** [GW]	**2030** [GW]	**2050** [GW]
ACTUAL INSTALLATIONS	**39**			
Greenpeace* (reference scenario)	14	80	184	420
Greenpeace* ([r]evolution scenario)	18	335	1,036	2,968
Greenpeace* (advanced scenario)	21	439	1,330	4,318
IEA Rwference Scenario**	10	30	<60	non competitive
IEA ACT Map	22	80	130	600
IEA Blue Map	27	130	230	1,150
IEA PV Technology Roadmap	27	210	870	3,155

* 2010 values are extrapolated, as only 2007 and 2015 values are given

Due to the long life-time of power plants (30 to 50 years), the decisions taken now will influence the socio-economic and ecological key factors of our energy system in 2020 and beyond. In addition, a 2003 IEA study pointed out that fuel costs will be in the same order of magnitude as investment in infrastructure. The price development over the last eight years has exacerbated this trend and increased the scale of the challenge, especially for developing countries.

The above-mentioned solar photovoltaic scenarios will only be possible if solar cell and module manufacturing are continuously improved, and novel design concepts can be realised, as with current technology the demand for some materials, like silver, would dramatically increase the economic costs for this resources within the next 30 years. Research to avoid such kinds of problems is underway and it can be expected that such bottle-necks will be avoided.

The photovoltaic industry is still changing from a MW size industry into a mass-producing industry aiming for multi GW production. This development is connected to an increasing industry consolidation, which presents a risk and an opportunity at the same time. If the new large solar cell companies use their cost advantages to offer lower-priced products, customers will buy more solar systems and it is expected that the PV market will show an accelerated growth rate. However, this development will influence the competitiveness of small and medium companies as well. To survive the price pressure of the very competitive commodity mass market, and to compensate the advantage of the big companies made possible by economies of scale that come with large production volumes, they have to specialise in niche markets with high value added in their products. The other possibility is to offer technologically more advanced and cheaper solar cell concepts.

Despite the fact that Europe – especially Germany – is still the biggest world market, the overall world market is gradually changing into a more balanced one. The internationalisation of the production industry is mainly due to the rapidly growing PV manufacturers from China and Taiwan, as well as new market entrants from companies located in India, Malaysia, the Philippines, Singapore, South Korea, UAE, etc. Should the current trend in the field of world-wide production capacity increase continue, the European share will decrease further. At the moment, it is hard to predict how the market entrance of the new players all over the world will influence future developments of the markets.

A lot of the future market developments, as well as production increases, will depend on the realisation of the currently announced and ongoing world-wide PV programmes and production capacity increases. During 2011 and the first half of 2012, the announcements from new companies wanting to start a PV production, as well as established companies to increase their production capacities, continued to increase the expected overall production capacity.

Already for a few years, we have now observed a continuous rise of oil and energy prices, which highlights the vulnerability of our current dependence on fossil energy sources, and increases the burden developing countries are facing in their struggle for future development. On the other hand, we see a continuous decrease in production costs for renewable energy technologies, as a result of steep learning curves. Due to the fact that external energy costs, subsidies in conventional energies and price volatility risks are generally not yet taken into consideration, renewable energies and photovoltaics are still perceived as being more expensive in the market than conventional energy sources. Nevertheless, electricity production from photovoltaic solar systems has already proved now that it can be cheaper than residential consumer prices in a wide range of countries. In addition, renewable energies are, contrary to conventional energy sources, the only ones to offer a reduction of prices rather than an increase in the future.

12. Acknowledgements

In addition to the numerous discussions I have had with international colleagues, as well as literature and internet research, various Government entities, research centres and leading industry companies were visited in China, India, Japan, the USA and Europe over the last years.
I would like to thank all my hosts for their kindness and the time they have taken to receive me, to share their knowledge and to discuss the status and prospects of photovoltaics.

13. References

[ADB 2011] Asian Development Bank, *Asia Solar Energy Initiative: A Primer,* ISBN 978-92-9092-314-5, April 2011

[Awe 2003] Shimon Awerbuch, The True Cost of Fossil-Fired Electricity in the EU: A CAPM-based Approach, January 2003.

[Blo 2012] Bloomberg new Energy Finance, PV Market Outlook Q3 2012, 7 August 2012

[Blo 2012a] Bloomberg new Energy Finance, Analyst Reaction - Solar, 17 August 2012

[Blo 2012b] Bloomberg new Energy Finance, Energy Research Note – Levelised Cost of Electricity Q3 2012, 18 July 2012

[Blo 2012c] Bloomberg New Energy Finance, Italy reaches a compromise on its solar bill, Solar – Analyst Reaction, 13 July 2012

[Blo 2012d] Bloomberg New Energy Finance, Solar and wind on course to employ 2m people by 2020, Wind, Solar Research Note, 5 March 2012

[Bsw 2012] Bundesverband Solarwirtschaft, Statuspapier Photovoltaik, June 2012

[Bsw 2012a] Bundesverband Solarwirtschaft, Statuspapier Photovoltaik, September 2012

[Bun 2012] German Federal Network Agency (Bundesnetz-agentur), Datenmeldungen für 2011

[CEU 2007] Council of the European Union, 8-9 March 2007, Presidency Conclusions 7224/07, 9 March 2007

[Cri 2012] China Research and Intelligence Co., Ltd. (CRI), Research Report on China's Polysilicon Industry, 2012, May 2012

[Dai 2011] The Daily Star, Target 500 MW solar project, 15 May 2011, http://www.thedailystar.net/newDesign/news-details.php?nid=185717

[DEC 2011] Department of Energy & Climate Change, Press Release, 7 February 2011

[Dsi 2012] Database of State Incentives for Renewable Energy (DSIRE), June 2011, http://www.dsireusa.org/

[DoE 2006] U.S. DoE Strategic Plan, 2006, http://www.energy.gov/about/strategicplan.htm

[DoE 2008] U.S. Department of Energy, April 2008, Solar Energy Technologies Programme (Solar Programme): *2008-2012 Multi-Year Programme Plan*

[DOE 2008a] DOE, Solar America Initiative, http://www1.eere.energy.gov/solar/solar_america/publications.html#technology_roadmaps

[EC 1996] European Commission, Directorate-General for Energy, Photovoltaics in 2010, Office for Official Publications of the European Communities, 1996, ISBN 92-827-5347-6

[EC 1997] Energy for the Future: Renewable sources of energy;
White Paper for a Community Strategy and Action Plan, COM(1997)599 final (26/11/97)

[EC 2000] Towards a European Strategy for the Security of Energy Supply;
Green Paper, COM (2000) 769 final

[EC 2005] Communication from the Commission;
The support of electricity from renewable energy sources; COM (2005) 627 (07.12.2005), {SEC(2005) 1571}

[EC 2005a] European Commission, DG ECFIN; REP – EN – 51952.

[EC 2001] Directive 2001/77/EC (27.09.2001);
Official Journal of the European Communities L 283/42 (27.10.2001)

[EC 2003] Directive 2003/30/EC (08.05.2003);
Official Journal of the European Communities L 123/33 (17.05.2003)

[EC 2007] C 3 / 2007 - Tarifs réglementés de l'électricité en Espagne
Official Journal of the European Communities, C 43/50 (27 February 2007)

[EC 2007a] Communication from the Commission to the Council, the European Parliament, the European Economic and Social Committee and the Committee of the Regions; *A European Strategic Energy Technology Plan (SET-Plan)* – Towards a low carbon future; 22 November 2007
COM(2007) 723 final, {SEC(2007) 1508}; {SEC(2007) 1509}; {SEC(2007) 1510}; {SEC(2007) 1511}

[EC 2009] Directive 2009/28/EC (23.04.2009);
Official Journal of the European Communities L 140/16 (05.06.2009)

[EC 2009a] Photovoltaic Solar Energy – Development and current research, 2009, Office for Official Publications of the European Union,
ISBN 978-92-79-10644-6

[EC 2011] Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, A Roadmap for moving to a competitive low carbon economy in 2050, 8 March 2011, COM (2011), 112 final, {SEC (2011) 287, 288, 289}

[EC 2012] Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, *Renewable Energy: a major player in the European Energy market,* COM(2012)271 final, 06 June 2012 {SWD(2012) 149 final, SWD(2012) 163 final, SWD(2012) 164 final}

[EEG 2000] Gesetz über den Vorrang Erneuerbaren Energien (Erneuerbare-Energien-Gesetz – EEG), Bundesgestzblatt Jahrgang 2000 Teil I, Nr. 13, p.305 (29.03.2000)

[Eia 2012] Energy Information Administration,
http://www.eia.DoE.gov/fuelelectric.html

[Eia 2012a] EIA, Annual Energy Outlook 2013,
U.S. Energy Information Administration, 2012

[Enf 2012] ENF Taiwanese Cell and Panel Manufacturers Survey, 3rd Edition - Individual Company Profiles, July 2012

[Epi 2009] European Photovoltaic Industry Association, 2009, SET For 2020 – Solar photovoltaic Electricity: A mainstream power source in Europe by 2020, www.setfor2020.eu

[Epi 2012] European Photovoltaic Industry Association, 2012, *Global Market Outlook for Photovoltaics until 2016*

[Ern 2011] Ernest & Young, Renewable energy country attractiveness indicator, November 2011, Issue 31

[Est 2011] Energy, transport and environment indicators, eurostat pocketbook, 2011 edition, Publications Office of the European Union, Luxembourg, ISBN 978-92-79-21384-7

[Est 2011a] Eurostat Statisics Explained, June 2011, http://epp.eurostat.ec.europa.eu/statistics_explained/index.php/Electricity_production_and_supply_statistics

[Est 2012] Eurostat Statistics, Energy Data Tables for 2010, accessed 10.10.2012

[Etc 2012] Facilitate Smooth Import to China, E-to-China.com, Press Release 4 September 2012

[Eup 2010] EuPD Research, May 2010, U.S. Solar Policy Impact analysis: Economic Impact of Extension of the Treasury Grant Programme (TGP) and Inclusion of Solar Manufacturing Equipment in the Investment Tax Credit (MITC)

[Ewg 2010] Energy Watch Group, March 2010, Abschätzung der jährlichen weltweiten Ausgaben für Energieversorgung
http://www.energywatchgroup.org

[FiT 2010] Financial Times, 6 June 2010, IEA counts $550 billion energy support bill

[Fir 2012] First Solar, Press Release, 17 April 2012

[Gaz 2012] Supplemento n. 143 alla Gazzetta n. 159 del 10/07/2012, Ministero dello sviluppo economico, decreto ministeriale 5 luglio 2012; Attuazione dell’articolo 25 del decreto legislativo 3 marzo 2011, n. 28, recante incentivazione della produzione di energia elettrica da impianti solari fotovoltaici (cd. Quinto Conto Energia)

[GoA 2006] Ley 26.190 - Ley de Energía Eléctrica (2006), Boletín Oficial de la República de Argentina, Número 31.064
http://www.diputados-catamarca.gov.ar/ley/B0020107.PDF

[GoB 2012] Bulgarian State Gazette, 10 April 2012, Decree 147/2012 from 28 March 2012, http://dv.parliament.bg/DVWeb/showMaterialDV.jsp?idMat=63208

[GoB 2012a] Bulgarian State Gazette, 17 June 2012, Law amending the Law on Energy, ORDINANCE 271 from 3 July 2012
http://dv.parliament.bg/DVWeb/showMaterialDV.jsp?idMat=66287

[GoC 2012] Government of Chile, Strategic Energy Plan, 28 February 2012
http://www.gob.cl/especiales/estrategia-nacional-de-energia/

[GoD 2007] Ley No. 57-07sobre Incentivo al Desarrollo de Fuentes Renovables de Energía y de sus Regímenes Especiales (Dominican Republic)

[GoH 2012] VLADA REPUBLIKE HRVATSKE, Narodne novine, br. 63/12, p 1508 ff, Tarifni sustav za proizvodnju električne energije iz obnovljivih izvora energije i kogeneracije (Tariff system for the production of electricity from renewable energy sources and cogeneration)
http://narodne-novine.nn.hr/clanci/sluzbeni/2012_06_63_1508.html

[GoI 2010] Ministry of New & Renewable Energy, Government of India, Solar Mission Document; http://mnre.gov.in/pdf/mission-document-JNNSM.pdf

[GoK 2010] Ministry of Energy, Kenya, Feed-in-Tariffs policy for wind, biomass, small hydros, geothermal, biogas and solar, 1st revision, January 2010
http://www.erc.go.ke/erc/fitpolicy.pdf

[GoM 2008] DECRETO por el que se expide la Ley para el Aprovechamiento de Energías Renovables y el Financiamiento de la Transición Energética, Diario Oficial (Primera Sección) 88, 28 November 2008 (Mexico)
http://www.diputados.gob.mx/LeyesBiblio/ref/laerfte/LAERFTE_orig_28nov08.pdf

[GoM 2011] Energy Act, Official Gazette of the Republic of Macedonia No.16/11, 136/11,

[GoM 2011a] Decree for Preferential (Feed-in) Tariffs for electricity, Official Gazette of the Republic of Macedonia" No.176/11

[GoM 2011b] Government of Montenegro, UREDBUO – TARIFNOM SISTEMU ZA UTVRđIVANJE PODSTICAJNE CIJENE ELEKTRIČNE ENERGIJE IZ OBNOVLJIVIH IZVORA ENERGIJE I VISOKOEFIKASNE KOGENERACIJE (Decree - The tariff system for determining the incentive Electricty Prices for Energy from Renewable Energy and High Efficiency Cogeneration)
http://www.oie-res.me/uploads/archive/News%202010/2011_Uredba%20o%20tarifnom%20sistemu%20za%20utvrdjivanje%20podsticajne%20cijene%20elektriene%20energije%20iz%20oie.pdf

[GoM 2012] Se Expide la Ley General de Chambio Climático, Diario Oficial (Segunda Sección) 1, 6 June 2012 (Mexico)
http://www.diputados.gob.mx/LeyesBiblio/ref/lgcc/LGCC_orig_06jun12.pdf

[GoS 2008] Act No. 34 of 2008: National Energy Act, Government Gazette, Republic of South Africa, Vol. 521, No 31638, 24 November 2008
http://www.info.gov.za/view/DownloadFileAction?id=92826

[GoS 2009] Incentives Decree, Uredba o merama podsticaja za proizvodnju elektriβne energije iz obnovljivih izvora energije i kombinovanom proizvodnjom električne i toplotne energije, Official Gazette of the Republic of Serbia No. 99/2009

[GoS 2012] Slovakian Ordinance No. 225/2011, 11 July 2011
http://www.urso.gov.sk/doc/legislativa/vyhl_225-2011.pdf

[GoS 2012a] Spanish Royal Decree 1/12, published on 28 January 2012
http://www.boe.es/boe/dias/2012/01/28/pdfs/BOE-A-2012-1310.pdf

[GoT 2005] Government of Turkey, Law No. 5346 on the Use of Renewable Energy Resources in Order to Generate Electricity (Yenilenebilir Enerji Kaynaklarının Elektrik Enerjisi Üretimi Amaçlı Kullanımına iliβkin Kanun), Official Gazette no. 25819 on 18 May 2005

[GoT 2008] Ministry of Economic Affairs, 5 June 2008, *Framework of Taiwan's Sustainable Energy Policy*

[GoT 2011] Government of Turkey, Official Gazette No. 27809, 8 January 2011.

[GoU 2003] Law of Ukraine "On Alternative Sources of Energy", No. 555-IV, 23 February 2003

[GoU 2006] Cabinet Resolution No.145, 15 March 2006

[Gre 2012] Greenpeace International, European Renewable Energy Council (EREC), Global Wind Energy Council (GWEC), Energy [r]evolution, 4th edition 2012 world energy scenario, July 2012, ISBN 978-90-73361-92-8

[GSE 2012] Gestore Servizi Energetici, Rapporto Statistico 2011 – Solare Fotovoltaico, 14 May 2012

[GSE 2012a] Gestore Servizi Energetici, conto energia – contatore fotovoltaico, 31 August 2012

[Gtm 2012] Greeentech Media Research, Polysilicon 2012

– 2016: Supply, Demand & Implications for the Global PV Industry, 18 January 2012

[Guj 2012] Gujarat Electricity Regulatory Commission, Determination of tariff for Procurement by the Distribution Licensees and others from Solar Energy Projects, Order No. 1 of 2012 http://www.gercin.org/renewablepdf/Solar%20Tariff%20Order%201%20of%202012.pdf

[Hau 2012] Frank Haugwitz, Deutsche China Consult (Beijing) Co. Ltd, Briefing Paper China, August 2012

[IEA 2010] International Energy Agency, 2010, Energy Technology Perspectives – Scenarios & Strategies to 2050, ISBN 978-92-64-08597-8

[IEA 2010a] International Energy Agency, 2010, PV Technology Roadmap

[IEA 2011] Joint report by IEA, OPEC, OECD and World Bank on fossil-fuel and other energy subsidies: An update of the G20 Pittsburgh and Toronto Commitments http://www.oecd.org/env/49090716.pdf

[IEA 2011a] International Energy Agency, 2011, World Energy Outlook, ISBN 978-92-64-12413-4

[IEA 2012] International Energy Agency, Medium-Term Renewable Energy Market Report 2012 - Market Trends and Projections to 2017, 182 pages, ISBN 978-92-64-17799-4 (2012)

[IEA 2012a] International Energy Agency, Co-operative Programme on Photovoltaic Power Systems, National Survey Report of PV Power Applications in China 2011, 15 August 2012

[IEA 2012b] International Energy Agency, Co-operative Programme on Photovoltaic Power Systems, National Survey Report of PV Power Applications in Korea 2011, 20 June 2012

[IEA 2012c] International Energy Agency, Co-operative Programme on Photovoltaic Power Systems, Trend Preview, 17 August 2012

[Ihs 2012] iSupply, Surplus Supply of Polysilicon Pressures Pricing – but not all Polysilicon Prices are Equal, Press release 18 April 2012

[Ikk 2012] Osamu Ikki, PV Activities in Japan, Volume 18, No 7, July 2012

[Ikk 2012a] Osamu Ikki, PV Activities in Japan, Volume 18, No 10, July 2012

[Ims 2012] IMS research, Press Release, 22 August 2012

[Isa 2010] Indian Semiconductor Association, Solar PV Industry 2010: Contemporary scenario and emerging trends, May 2010

[Jäg 2010] Arnulf Jäger-Waldau, PV Status Report 2010, Office for Official Publications of the European Union, EUR 24334 EN, ISBN 978-92-79-15657-1

[Jäg 2011] Arnulf Jäger-Waldau, PV Status Report 2011, Office for Official Publications of the European Union, EUR 24807 EN, ISBN 978-92-79-20171-4

[JRC 2011] JRC Reference Report, 2011, EUR 24926 EN, M. Szabo, A. Jäger-Waldau, F. Monforti-Ferrario, N. Scarlat, H. Bloem, M. Quicheron, T. Huld, H. Ossenbrink, Technical Assessment of the Renewable Energy Action Plans, Publications Office of the European Union, ISBN 978-92-21049-5 (online)

[Kor 2012] The Korea Times, US solar firm to invest $320 mil. in Daegu, 05 June 2012

[MCI 2012] Ministry of Commerce, Industry & Tourism, Cyprus, Grant Scheme for the Promotion of Electricity Generation using Wind, Solar Thermal, Photovoltaic Systems and the Utilization of Biomass (2012 – No.3), V10 09/05/2012

[MEI 2011] Ministère de l`Économie, de l'industrie et de l'emploi, Press Release, 24 February 2011

[Mer 2012] MERCOM Capital Group, Indian Solar Market update – 2nd quarter 2012, 5 September 2012

[MII 202] Ministry of Industry and Information Technology, 太阳能光伏产业"十二五"发展规划 (issuance of the solar photovoltaic industry, "second five" development plan "), 24 February 2012 http://www.miit.gov.cn/n11293472/n11293832/n12771663/14473764.html

[Min 2012] Paula Mints, CPV – To Infinity and Beyond!, Navigant Consulting Webinar, 18 July 2012

[Mer 2012] MERCOM Capital Group, Solar Market Intelligence Report, 24 September 2012

[NDR 2011] National Development and Reform Commission, "Notice from National Development and Reform Commission Regarding the Solar Photovoltaic Power On-grid Tariff Policy" (Fa Gai Jia Ge [2011] No. 1594)國家發展改革委關於完善太陽能光伏發電上網電價政策的通知;（發改價格[2011]1594β 24 July 2011

[NEA 2012] National Energy Administration, 可再生能源发展"十二五"规划发布 Press Release, 8 August 2012 http://www.nea.gov.cn/2012-08/08/c_131767651.htm

[NED 2007] NEDO Brochure, Energy and Environment Technologies, December 2007 http://www.nedo.go.jp/kankobutsu/pamphlets/kouhou/2007gaiyo_e/87_140.pdf

[Nre 2012] Clean Energy Solutions Centre http://maps.nrel.gov/global_re_opportunity#

[Ont 2012] Ontario Power Authority, 10 August, 2012: Final FIT 2.0 http://fit.powerauthority.on.ca/august-10-2012-final-fit-20-program-documents-posted

[Oss 2012] H. Ossenbrink, A. Jäger-Waldau, T. Huld, N. Taylor, New Opportunities for PV Systems, Proceedings of the 27th European Photovoltaic Energy Conference and Exhibition, 24 to 28 September 2012, Frankfurt, Germany

[PEW 2012] The Pew Charitable Trust, Who's winning the Clean Energy Race? 2011 Edition, 2012

[Ptp 2007] PV Technology Platform: *Strategic Research Agenda for Photovoltaic Solar Energy Conversion Technology,* June 2007, Luxembourg: Office for Official Publications of the European Communities, ISBN 978-92-79-05523-2

[Ptp 2009] PV Technology Platform: Today's actions for tomorrow's PV technology – An Implementation Plan for the *Strategic Research Agenda of the European Photovoltaic Technology Platform*, August 2009, Luxembourg: Office for Official Publications of the European Union, ISBN 978-92-79-12391-7

[Pvm 2012] PV magazine, 30 July 2012, http://www.pv-magazine.com/news/details/beitrag/india–1-gw-milestone-crossed_100007931/

[Pvn 2012] PV News, May 2013, published by Greentech Media, ISSN 0739-4829

[Pho 2011] Photon International, March 2012

[Raj 2012] Rajasthan Renewable Energy Corporation, 20 March 2012 http://www.rrecl.com/PDF/Invitation%20of%20RfS%20for%2050%20Nos.%20of%201%20MW%20projects%2020.03.2012.pdf

[Raj 2012a] Rajasthan Electricity Regulator Commission, Order 127 of 30 May 2012 http://www.rerc.rajasthan.gov.in/TariffOrders/Order127.pdf

[Reu 2012] Reuters, 8 August 2012, China hikes 2015 solar power target by 40%

[RoI 2006] Presidential Regulation 5/2006, *National Energy Policy*, published 25 January 2006

[RoP 2008] Republic of the Philippines, Congress of the Philippines, Republic Act No. 9513 16 December, 2008, AN ACT PROMOTING THE DEVELOPMENT, UTILIZATION AND COMMERCIALIZATION OF RENEWABLE ENERGY RESOURCES AND FOR OTHER PURPOSES

[Rts 2012] RTS Corporation, PV market in Japan 2011/2012

[See 2012] J. Seel, G. Barbose and R. Wyser, Why are Residential PV Prices in Germany so much Lower than in the United States? A scoping Analysis, September 2012

[Sei 2010] Solar Europe Industry Initiative, Implementation Plan 2010-2012 http://ec.europa.eu/energy/technology/initiatives/initiatives_en.htm

[Sei 2012] Solar Energy Industry Association (SEIA), U.S. Solar Market Insight, U.S Solar Industry Year in Review 2011

[Sei 2012a] Solar Energy Industry Association (SEIA), U.S. Solar Market Insight, Q2 2012, Executive Summary

[Sew 2012] Bulgarian State Energy and Water Regulation Commission, DECISION № Ц-33, 14 September 2012, http://www.dker.bg/files/DOWNLOAD/res-tseni-dostap-VI-proizv.pdf

[Sol 2012] *Solarbuzz, Supply/Demand Balance Restored to PV Industry in Second Half of 2012*, 25 June 2012 (http://www.solarbuzz.com)

[Sol 2012a] Solar PV Investor, Polysilicon Capacity 2010 – 2013

[Sta 2009] Seizing the Solar Solution: Combating Climate Change through Accelerated Deployment, December 2009, A joint Report by all the Solar Associations around the world, published by EPIA and SEIA, www.solarcop15.org

[Sur 2004] PV Electricity Potential in EU25 Member States, M. Šúri, T. Huld, E. Dunlop, in "Status Report 2004 - Energy End-use Efficiency and Electricity from Biomass, Wind and Photovoltaics in The European Union", ed. A. Jäger-Waldau, European Commission, DG JRC Euro Report No. EUR 21297 EN; Luxembourg: Office for Official Publications of the European Communities, 2004; ISBN 92-894-8193-5

[Sys 2012] Systèmes Solaires, le journal du photovoltaique no 7 – 2012, Photovoltaic Energy Barometer, April 2012, ISSN 0295-5873

[Ter 2012] Terna, Analyst Presentation, 20 March 2012

[Unb 2011] UNB connect, ADB assures fund for 500 MW solar system, 4 June 2011, http://www.unbconnect.com/component/news/task-show/id-49440

[Unb 2012] UNB connect, 50,000 new rural homes getting solar electricity every month , 26 June 2012, http://unbconnect.com/component/news/task-show/id-80519

[UNEP 2008] Reforming Energy Subsidies - Opportunities to Contribute to the Climate Change Agenda United Nations, United Nations Environment Programme, 2008, http://www.unep.org/pdf/pressreleases/reforming_energy_subsidies.pdf

[Uni 2009] Union of Concerned Scientists, Successful Strategies: Renewable Electricity Standards, Fact Sheet, February 2009, http://www.ucsusa.org/

[Uni 2012] Union of Concerned Scientists, Renewable Electricity Standards Toolkit: Projected Growth of Renewable Electricity, http://www.ucsusa.org/clean_energy/res/overviewgrowth.html

[WoB 2010] The World Bank, May 2010, Winds of Change – East Asia's Sustainable Energy Future

[WoB 2012] The World Bank, 13 June 2012, Electricity from Solar Panels Transforms Lives in Rural Bangladesh

[Zwe 2007] Ken Zweibel, James Mason and Vasilis Fthenakis, *A Solar Grand Plan,* Scientific American, 16 December 2007

European Commission

EUR 25749 – Joint Research Centre
– Institute for Energy and Transport

Title: **PV Status Report 2012**
Author: Dr. Arnulf Jäger-Waldau

Luxembourg: Publications Office of the European Union

2012 – 118 pp. – 21.0 x 29.7 cm

EUR – Scientific and Policy Report series

ISBN 978-92-79-26072-8 (online)

ISSN 1977-7086/1831-9424 (online)

doi: 10.2788/44375 (online)

Abstract

Photovoltaics is a solar power technology to generate Electricity using semiconductor devices, known as solar cells. A number of solar cells form a solar “Module” or “Panel”, which can then be combined to solar systems, ranging from a few Watts of electricity output to multi Megawatt power stations.

The unique format of the Photovoltaic Status Report combines international up-to-date information about Research Activities with Manufacturing and Market Implementation Data of Photovoltaics. These data are collected on a regular basis from public and commercial studies and cross-checked with personal communications. Regular fact-finding missions with company visits, as well as meetings with officials from funding organisations and policy makers, complete the picture.

Growth in the solar Photovoltaic sector has been robust. Yearly growth rates over the last decade were on average more than 40%, thus making photovoltaics one of the fastest growing industries at present. The PV Status Report provides comprehensive and relevant information on this dynamic sector for the public interested, as well as decision- makers in policy and industry.

How to obtain EU publications

Publications for sale:

- via EU Bookshop (http://bookshop.europa.eu);
- from your bookseller by quoting the title, publisher and/or ISBN number;
- by contacting one of our sales agents directly. You can obtain their contact details on the Internet (http://bookshop.europa.eu) or by sending a fax to +352 2929-42758.

Free publications:

- via EU Bookshop (http://bookshop.europa.eu);
- at the European Commission's representations or delegations. You can obtain their contact details on the Internet (http://ec.europa.eu) or by sending a fax to +352 2929-42758.

LB-XB-12-001-EN-N

As the Commission's in-house science service, the Joint Research Centre's mission is to provide EU policies with independent, evidence-based scientific and technical support throughout the whole policy cycle.

Working in close cooperation with policy Directorates-General, the JRC addresses key societal challenges while stimulating innovation through developing new standards, methods and tools, and sharing and transferring its know-how to the Member States and international community.

Key policy areas include: environment and climate change; energy and transport; agriculture and food security; health and consumer protection; information society and digital agenda; safety and security including nuclear; all supported through a cross-cutting and multi-disciplinary approach.

Publications Office

ISBN 978-92-79-26072-8

9 789279 260728